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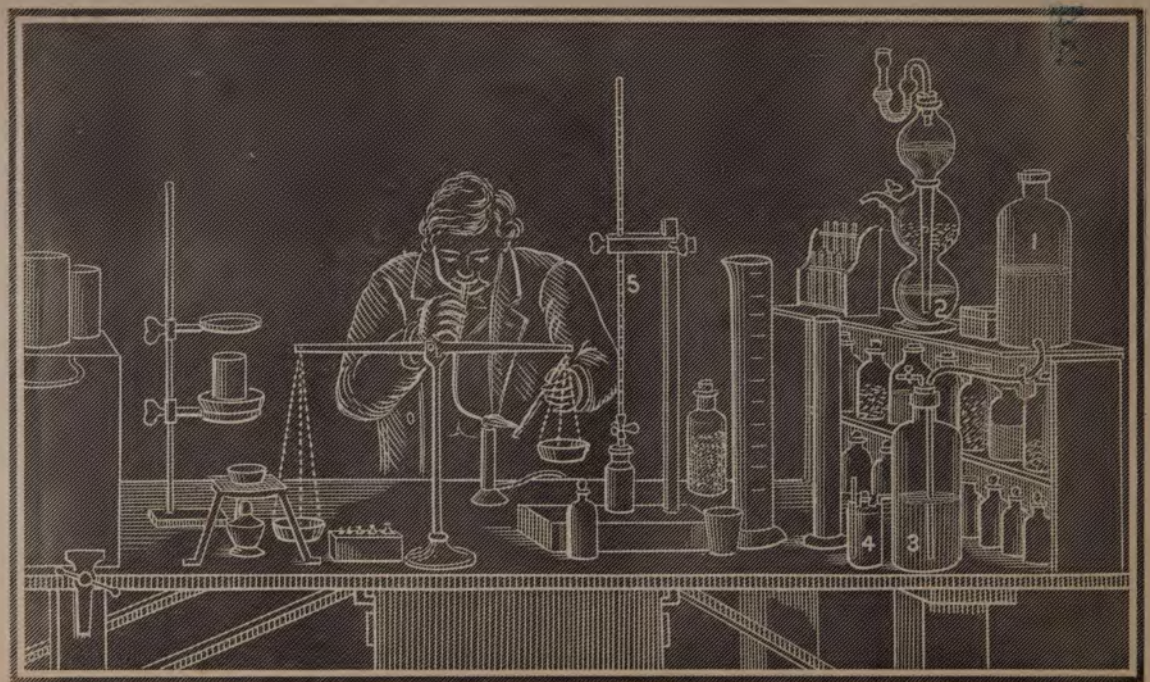
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CHEMICAL PRIMER:

AN ELEMENTARY WORK

FOR USE IN

HIGH SCHOOLS.

BY

S. P. MEADS.

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PREFACE.

THIS Primer has been prepared for use in those High Schools that can give to chemistry only one term's work. It has grown out of the needs of the class-room, as I have felt them. Its statements are necessarily somewhat narrow, confining the pupil to general rules. Refined accuracy means a treatise, not a primer. The book is as accurate as painstaking can make a work of its aim and scope. I have given in its pages as much as I think the average High School class can digest in a single term, and I hope my fellow-teachers will carefully examine the plan *throughout* before passing judgment.

I have freely consulted whatever chemical works were within my reach, especially Attfield, Roscoe and Schorlemmer, Eliot and Storer, Appleton, and Barker. I am greatly indebted to Prof. W. B. Rising for his kindness in helping me down from the fence upon the right side in not a few instances—indeed, I might say *over* the fence, in some cases. My thanks are due my worthy Principal, Mr. J. B. McChesney, for his uniform encouragement. I am under lasting obligation to my esteemed co-laborer in the High School, Mr. C. B. Bradley, for his patient assistance. Many ambiguous and obscure statements, that came too carelessly from my pen, have been made clear and intelligible by his scholarly criticism.

Natural Science Dept., S. P. MEADS.
Oakland High School, May 1, 1882.

106174

Brief Suggestions---Mixed.

DO not allow pupils lazily to pronounce the symbol or the formula instead of the name; *i. e.:* wherever "H" occurs, see that it is called hydrogen.....Have the pupils copy the two Reference Tables (pp. 16, 28) upon cardboard, and allow them the free use of these for the entire term. Never compel them to memorize formulas, atomic weights, strength, etc. It is as important to know what not to remember, as to know what should be remembered, since the former comprises by far the larger portion of any text-book.....Let the pupils perform all experiments (except, perhaps, a few difficult ones, or for the sake of taking your turn with the class) in presence of the class, explaining each experiment as it proceeds. It takes time, but it is the only way to teach chemistry where a table for each student cannot be provided. If you haven't time, omit half the experiments to accomplish this result. Assign to separate pupils one experiment each a few days beforehand. The experiments may be performed upon a redwood (plank) table (see FRONTISPIECE), costing not over three dollars..... *Every* experiment teaches something, and the sooner you can impress this fact the better. While you should make every experiment as impressive as it can be made, get the pupils through the babyhood which craves noisy or showy experiments, as early in the term as possible.....See that a number of larger works upon chemistry are at your desk for reference. ....After you have passed the "Reactions," encourage any pupils *who may show a special liking for the science* to work out a number of solutions (not too complex, and mixed by you) by the Analytical Charts.....Teach pupils to use small flasks and *small quantities of chemicals.* It isn't necessary to burn a forest to prove that hydrocarbons are combustible, nor to blow up a continent to prove a substance explosive.....Don't be afraid to teach anything contrary to the text, *if you have good authority for it;* but let disputed points alone.....Teach any simple principles beyond the text, instead of others more complex omitted; but don't teach intricate matter outside of text, else the result will be pupils will know neither the text nor the "intricate matter."....Use the metric system throughout; it is *the* system. Use either thermometer. The CENTIGRADE is used in this book.

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CHAPTER I.

INTRODUCTION.

MATTER exists in three states:—

1. **Solid**: Ex., iron, lead, ice.
2. **Liquid**: Ex., mercury, bromine, water.
3. **Gaseous**: Ex., hydrogen, air, steam.

Nearly all substances ordinarily in the solid state may, by applying *heat* (and removing pressure), be made first liquid and then gaseous. Nearly all gases, by *cold* and *pressure*, may be made first liquid and then solid.

A change which *merely* converts a solid to a liquid, or a liquid to a gas, or *vice versa*, however wonderful such change may be, is not a chemical, but a physical change. Ex., Ice may be heated and converted into water, a liquid, and then into steam, a gas.

All such changes are studied in *Physics*, not in *Chemistry*. Chemistry deals with such changes only incidentally.

The molecules (small, invisible particles) of a solid move with difficulty upon each other. The molecules of a liquid move readily upon each other, so that the liquid assumes the shape of the vessel holding it. The molecules of gas have an apparent repulsion for each other, so that a gas, regardless of its specific gravity (*i. e.* whether *light* or *heavy*), escapes from an open vessel and diffuses itself throughout the surrounding space.

CHAPTER II.

The **Atomic Theory** divides matter into:—

1. **Mass.**—Any portion of matter *appreciable by the senses.*

2. **Molecule.**—The smallest particle of matter that can take part in a mere physical change. It may exist alone.

3. **Atom.**—The smallest particle of matter that can take part in a chemical change. An atom does not exist alone. Atoms compose molecules; *i. e.*, two or more atoms make a molecule.

Chemistry treats of the atomic condition of matter and especially of atomic changes.

It will be inferred from the definitions that a *mass* may be very large or exceedingly small, also, that the molecule and the atom are not visible even with the aid of the most powerful microscope, otherwise *they* would be "appreciable by the senses."

Chemistry treats of more subtle changes than physics. If the molecule is not broken up and the *atoms* set free to form new combinations, it matters not how violent, or how wonderful the change may be, it is purely *physical* and in no sense chemical.

Of course, atoms "exist alone" during the instant of chemical change. One atom may rarely make a molecule. At this stage the pupil should fix the great rules, and not trouble himself with exceptions.

CHAPTER III.

An **Element** is a substance whose molecules contain atoms of one kind only; therefore it cannot be separated into two or more different kinds of substances. Ex., gold, lead, hydrogen.

A **binary** compound is a substance which has *two* different kinds of atoms in its molecule, and therefore, can be separated into two different kinds of substances. Ex., water, common salt.

A molecule of hydrogen may be represented thus $\boxed{\mathbf{H\ H}}$ in which each **H** represents an atom and the boundary line simply the fact that the two atoms of hydrogen are bound together by chemical bonds into one molecule.

A molecule of water may be represented thus $\boxed{\mathbf{HOH}}$ or more briefly, thus $\boxed{\mathbf{H_2O}}$ or still more briefly by omitting the boundary line, thus $\mathbf{H_2O}$. This means that in a molecule of water there are two atoms of hydrogen and one atom of oxygen.

Practically it means that *two* parts *by volume* of hydrogen unite with *one* part *by volume* of oxygen to form the binary compound which we call water. (Take this for granted now: we'll prove it by and by. See WATER, index). Thus, two *gases* unite to form a liquid. But this is a chemical change, because the atoms of the molecules of hydrogen and of oxygen are disturbed, their molecules being broken up to form new molecules of a *different* substance, water. The change may be represented thus:—

$$\boxed{\mathbf{HH}}\ \boxed{\mathbf{HH}} + \boxed{\mathbf{OO}} = \boxed{\mathbf{H_2O}}\ \boxed{\mathbf{H_2O}}$$

This means that two molecules of hydrogen and one molecule of oxygen break up into separate atoms and then instantaneously re-unite into two molecules of water.

The atomic reaction (beginning at the instant when the molecules are broken up) may be written thus:—

H_2	+	O	=	H_2O
Two atoms of hydrogen.		One atom of oxygen.		One molecule of water.

Chemical changes are called Reactions. For all practical purposes the atomic reaction is correct. As it is not nearly so difficult as the molecular reaction (first above) it alone will be used in this book.

There are about *sixty-seven* elements known, and these may be considered the alphabet of chemistry. From these all chemical compounds are formed, as words from letters. A binary compound might be compared to a word of two letters.

CHAPTER IV.

Atoms of different elements differ in three essential respects:—

1. In **weight.**
2. In **quality.**
3. In **strength.**

The **First Difference** needs no explanation. When we say that atoms differ in weight, we mean that they differ in weight. (Atoms of the same element have always the same weight).

The **Second Difference** needs explanation. The quality of meat may be determined *by eating* it, and the quality is said to be *good* or *bad.* The quality of cloth may be told *by wearing* it, and the quality of cloth is also said to be good or bad, as the case may be.

The quality of an atom is determined by **electricity,** and the atom is said to be, not *good* or *bad,* but **positive** or **negative.**

If a current of electricity from two or more of Bunsen's quart cups be passed through the binary compound water, the water will be decomposed and bubbles of gas will appear at each pole. If the gas from the positive pole be collected (see Fig. No. 1) and tested, it will prove to be oxygen. If the gas from the negative pole be collected and tested, it will prove to be hydrogen and will have twice the volume of the oxygen.

NOTE.—The water should be acidulated slightly with sulphuric acid. The hydrogen will always have a little more than twice the volume of the oxygen, because the liberated oxygen is more soluble in (the remaining) water than the hydrogen. The pupil may learn right here, that *a gas can be dissolved in water just as well as a solid.* The nature of a mere solution will be explained hereafter.

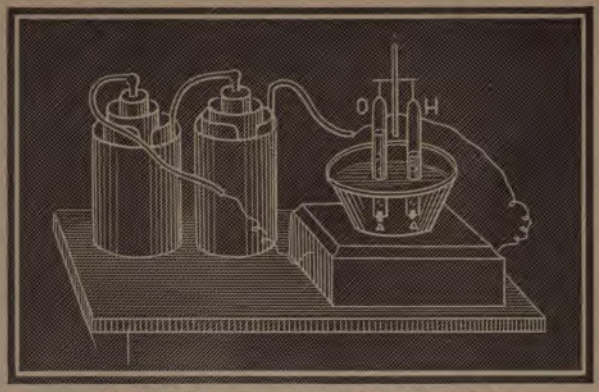


Fig. 1. A A—Platinum Ends (poles, or electrodes).

The law of electricity being that *"like electricities repel each other and unlike attract,"*—as oxygen goes to the positive pole, it is *negative* to hydrogen, and as hydrogen goes to the negative pole, it is *positive* to oxygen.

Thus, by means of a battery acting upon their compounds, the elements may be arranged with reference to their "quality,"—but an atom of an element is always positive or negative, not absolutely, but relatively.

For example, if we arrange in line sixty-seven boys from north to south, the first boy would be a *north* boy to any other. The second boy would be a south boy compared with the *first*, but a north boy compared with the *third*. The tenth boy would be a south boy compared with the fourth, but a north boy compared with the fifteenth. Any boy would be a south boy to all boys north of himself, but a north boy to all boys south of himself.

Thus, the elements are arranged in line according to their "quality," oxygen standing first, being most negative. (See Reference Table No. 1). This difference in "quality" is of the utmost importance in chemistry.

The **Third Difference** may be explained by an illustration.

If one man can hold a 100 lb. weight, we may call his strength *one*. Then, if another man can hold two 100 lb. weights, his strength would be *two*, and it would take two of the first kind of men to match one of the second kind. If a third man can hold three 100 lb. weights, his

strength would be three, and it would take three of the first kind of men to match one of the third. But how shall we match the second kind of men and the third kind? Evidently, three of the second kind would match two of the third kind. If a fourth man can hold four 100 lb. weights, his strength will be *four*; etc.

The strength of atoms is measured, not by 100 lb. weights, but by the strength of hydrogen atoms. The strength of the hydrogen atom is taken as *one*. The strength of those elements whose atoms each require one atom of hydrogen to match them is *one*;—of those elements whose atoms each require two atoms of hydrogen to match them, the strength is *two*;—of those whose atoms require three atoms of hydrogen, the strength is three, etc.

These elements are called respectively monads (1), dyads (2), triads (3), tetrads (4), pentads (5), hexads (6), and heptads (7). This strength of the atoms is often expressed adjectively by the terms, univalent (1), bivalent (2), trivalent (3), quadrivalent (4), pentivalent (5), etc.

CHAPTER V.

The names of the elements are abbreviated in chemical language. O is the symbol for oxygen, S for sulphur, Sb for antimony (Latin, *stibium*), etc. The dictionary will give the Latin name from which a number of the symbols are derived.

The following **Reference Table** exhibits the symbols of the elements and the *three* essential differences of their atoms:—

REFERENCE TABLE No. 1.

SYMBOL.	QUALITY. Shown by order of names.	ATOMIC WEIGHT.	STRENGTH.
	Negative End.		
O	Oxygen	16	2
S	Sulphur	32	2
N	Nitrogen	14	3
F	Fluorine	19	1
Cl	Chlorine	35.5	1
Br	Bromine	80	1
I	Iodine	127	1
$\overline{CN}$	Cyanogen*	26	1
Se	Selenium	79	2
P	Phosphorus	31	5
As	Arsenicum	75	3
Cr	Chromium	52.5	2
B	Boron	11	3
C	Carbon	12	4
Sb	Antimony	122	3
Si	Silicon	28	4
H	**HYDROGEN**	**1**	**1**
Au	Gold	196.6	3
Pt	Platinum	197	4
Hg	Mercury	200	2 (and Hg_2 a dyad)
Ag	Silver	108	1
Cu	Copper	63.5	2 (and Cu_2 a dyad)
Bi	Bismuth	210	3
Sn	Tin	118	4
Pb	Lead	207	2
Co	Cobalt	59	2
Ni	Nickel	59	2
Fe	Iron	56	2 (and Fe_2 a hexad)
Zn	Zinc	65	2
Mn	Manganese	55	2
Al	Aluminum	27.5	(Al_2 a hexad)
Mg	Magnesium	24	2
Ca	Calcium	40	2
Sr	Strontium	87.5	2
Ba	Barium	137	2
Na	Sodium	23	1
K	Potassium	39	1
$\overline{H_4N}$	Ammonium*	18	1
	Positive End.		

Above. Below.

*Not elements. (See Chap. VI).

CHAPTER VI.

A **binary compound** is named by placing the positive element first and changing the ending of the negative into **ide.**

EXAMPLE.

Formula.		Name.
Na Cl	=	sodium chlor**ide.**
K_2O	=	potassium ox**ide.**

It will be noticed that sodium and chlorine are both monads (see strength in Reference Table No. 1), and therefore it requires *one* atom of each to match the other in the molecule, as in the first example. In the second example, potassium is a monad (see TABLE), but oxygen is a dyad, therefore it takes *two* atoms of potassium to match *one* of oxygen in the molecule.

Again, in putting dyads and triads together, we must take *three dyads* to match *two triads* in the molecule, a strength of two times three equaling a strength of *three* times *two.*

EXAMPLE.

As_2S_3 = Arsenicum sulphide.

Again, two dyads must be taken to match one tetrad.

EXAMPLE.

CO_2 = Carbon oxide.

Five dyads must be taken to match two pentads.

EXAMPLE.

P_2O_5 = phosphorus oxide.
P_2S_5 = phosphorus sulphide.

NOTE.—Just as we sometimes say "the father of Mary," instead of "Mary's father," the older chemists say "sulphide of phosphorus," instead of "phosphorus sulphide." (They also expressed the same by "sulph*uret* of phosphorus," or "sulphuretted phosphorus.")

Atoms of two or more elements bound together by chemical bonds so closely, as to act as one atom in the formation of compounds, form a **Compound Radical.**

Two very important compound radicals are inserted in the Reference Table and linked with the elements with which they are closely allied. Their compounds with a single element are considered and named as binaries, though they contain *three* different kinds of atoms.

EXAMPLE.

$K\overline{CN}$ = potassium cyanide.
$(\overline{H_4N})_2S$ = ammonium sulphide.
$\overline{H_4N}\ \overline{CN}$ = ammonium cyanide.

Fig 2.

NOTE.—The pupil should write the formulas and names of a great many binary compounds, putting the atoms together according to the strength in the Reference Table. Be careful that the multiplications make the positives match in strength the negatives, as in the examples. It does not matter if many of the compounds are merely theoretical. It is, however, a great gain at this point, to have as many binaries *as combine according to the strength given in the Table,* shown to the scholars. For instance, a substance might be shown and the class told that it was a compound of sulphur and sodium. They should then all write labels for the bottle containing it, giving formula and name, as in Fig 2.

CHAPTER VII.

Ic and Ous Binaries.

These may be introduced by an illustration. In one of our eastern townships lived a man, who was afflicted with periodic insanity. When in his right mind (ordinarily), he had the strength of his brother. He could be called a *monad.* In one of his insane fits he carried three men upon his back over a gate five boards high. He became a very decided *triad,* you see.

Now, the **Reference Table No. 1** gives the "strength" of chlorine *one*; *i. e.* as a monad,—but sometimes it acts with a strength of three, *i. e.*, as a triad (sometimes as a pentad, or even as a heptad).

Carbon is given a strength of four, and this it ordinarily has,—but sometimes it acts with a strength of only *two*. Thus, it forms two binary compounds with oxygen, CO_2 and **CO**. Evidently, if we say carbon oxide, we shall not know which is meant, because the name may apply to either.

As a rule, an atom with an *even* strength never has an *odd* strength, also, an atom with an *odd* strength never has an *even* strength. The strength increases or decreases by *twos*. This will be noticed as we proceed.

We must invent some way to distinguish the different compounds, when an element acts with different strengths.

When the positive takes **more** of the negative, it has the ending **ic**, when it takes **less** of the negative, it has the ending **ous**.

EXAMPLE.

CO_2 = carbon**ic** oxide.
CO = carbon**ous** oxide.

When the positive takes *more* of the negative, than in the *ic* compound, it has the prefix *per* (from *hyper* = more); when it takes *less* of the negative, than in the *ous* compound, it takes the prefix *hypo* (under).

EXAMPLE.

(**SO** = *hypo*-sulphur*ous* oxide).
SO_2 = sulphur*ous* oxide.
SO_3 = sulphur*ic* oxide.
S_2O_7 = *per*-sulphur*ic* oxide.

NOTE.—*Per* and *hypo* are sometimes prefixed to the negative instead of to the positive. The first example above is theoretical, there being no such *free* compound. Few elements form *hypo*- and *per*-binaries, and the pupil will be troubled very little with them. They are given here, so that if, in the larger text-books, he sees *hypo*- and *per*-binaries mentioned, he may have some idea of what is meant.

The scholar should here solve many problems, such as the following:—

1. Put together sulphur and antimony to form two compounds giving antimony a strength in the first compound *as in the Table*, and in the second compound a strength of *five* (which it sometimes has). Name one *ic*, the other *ous*.

Ans. Sb_2S_3 = antimon*ous* sulphide.
Sb_2S_5 = antimon*ic* sulphide.

2. Put together iodine and mercury, giving mercury a strength, first, as in Table; second, as in the parenthesis of Table. Name.

Ans. HgI_2 = mercur*ic* iodide.
Hg_2I_2 = mercur*ous* iodide.

NOTE.—In this last compound, mercury *seems* to be a monad, *i. e.*, it *seems* to change from the *even* to the *odd* strength. A few of the other elements do the same thing, as you will see. For practical purposes, this last formula has sometimes been written HgI = mercur*ous* iodide, but it is better to write as above.

The *ic* and *ous* compounds of the same elements often differ very much in physical and chemical properties. You will see, by looking at the samples from the laboratory, that mercur*ic* iodide is *red*, while mercur*ous* iodide is *green*. Again, carbon*ic* oxide is *not* poisonous, while carbon*ous* oxide *is* poisonous.

A binary *may* be named by prefixing the Greek numerals (*mon, di, tri, tetra, etc*). In all cases where a mistake would be likely to occur, this very exact method is used.

EXAMPLE.

CO = carbon monoxide. (*ous.*)
CO_2 = carbon di-oxide. (*ic.*)
Fe_3O_4 = tri-ferric tetroxide.
Fe_2O_3 = di-ferric trioxide. (*ic.*)

NOTE.—The older chemists used, as a rule, *per* and *proto* for *ic* and *ous* respectively, as:—

FeO = *proto*xide of iron, instead of ferrous oxide.
Fe_2O_3 = *per*oxide of iron, instead of ferric oxide.

Instead of *ous*, the prefix *sub* was also used, as: Hg_2Cl_2 = *sub*-chloride of mercury.

Compounds, in which there were *two* of the positive to *three* of the negative, often took the prefix *sesqui* (one and one-half), as:—

Fe_2O_3 = sesquioxide of iron.

CHAPTER VIII.

Inspection of the following questions and the methods of solution will reveal the great value of the Atomic Theory to the chemist, and indeed, to the world of industry.

1. In 116 kilograms* of mercuric sulphide (Hg S) how much mercury?

Hg = 200 atomic weight (see Table).
S = 32 " "

Hg S = 232 molecular weight.

232 kgs. of Hg S corresponds to 200 kgs. of Hg.
1 " " = $\frac{1}{232}$ of 200 kgs. of Hg.
116 " " = $\frac{116}{232}$ of 200 " "
$\frac{116}{232}$ of 200 = 100 kgs. of Hg. *Ans.*

2. How much lead chloride ($Pb Cl_2$) could be made from 50 grams of lead?

Pb = 207 at. wt.
Cl_2 = 71 "

$Pb Cl_2$ = 278 mol. wt.

207 Pb = 278 $Pb Cl_2$
1 " = $\frac{1}{207}$ of 278 $Pb Cl_2$
50 " = $\frac{50}{207}$ of 278 "

278
50

207)13900(67$\frac{31}{207}$ grams. *Ans.*
1242

1480
1449

31

*See metric system.

It will be noticed that there are two distinct kinds of questions. The first gives the weight of the binary and requires the weight of the element. The second gives the weight of the element and requires the weight of the binary. In the first class of questions, of course, the answer is *less* than the given weight. In the second class the answer is *more* than the given weight. After obtaining the molecular weight by the addition of the atomic weights, decide whether your answer is to be *greater* or *less* than the given weight, and arrange the first equation below the molecular weight accordingly.

3. From one metric ton of the iron ore hematite (Fe_2O_3, ferric oxide), how many kilograms of iron could be obtained, provided the hematite contained 25 per cent. of earthy impurities, or waste?

1 M. T. = 1000 kgs.
25 per cent. waste leaves 75 per cent.

750 kgs. of pure ore.

Fe_2 = 112 at. wt.
O_3 = 48 "

Fe_2O_3 = 160 mol. wt.

160 Fe_2O_3 = 112 Fe
1 " = $\frac{1}{160}$ of 112 Fe
750 " = $\frac{750}{160}$ of 112 Fe = 525 kgs. iron. *Ans.*

NOTE.—The pupil should perform very many problems similar to the above. To show one common process of getting the element from the ore, heat some lead oxide (litharge) on charcoal (carbon) in the blowpipe flame. The carbon takes the oxygen from the lead, forming carbonic oxide (CO_2) and leaves the lead *free, i. e.*, not combined with any other element (See Exp. 50).

4. How much lead in 100 kgs. of lead oxide (PbO)? *Ans.* $92\frac{184}{223}$.

5. One M. T. of lead would make how many kilograms of litharge? *Ans.* $1077\frac{61}{207}$.

CHAPTER IX

A **ternary compound** is one having *three* different kinds of atoms in its molecule.

Most ternaries contain oxygen as a *connecting* element; it is therefore omitted in the name. It is *understood* to be the connecting element, unless otherwise mentioned (See Chap. XXIII). It is not omitted in the formula.

A ternary is named by placing the positive first and (the O being omitted) the negative last, with the ending changed into **ate.**

EXAMPLE.

$K\overline{ClO_3}$ = potassium chlor**ate.**

$H_2\overline{SO_4}$ = hydrogen sulph**ate.**

As in binaries, we have different compounds of the same *three* elements, and so must have different names.

When the **O** is *less* (relatively to the negative) than in the **ate** compound, the negative takes the ending **ite.**

Rarely the **O** may be *less* than in the *ite* compound, when *hypo*..... *ite* is used. Sometimes the **O** is *more* than in the *ate* compound, when *per* .....*ate* is used.

EXAMPLE.

K $\overline{\mathbf{ClO}}$ = potassium *hypo*-chlor*ite.*

K Cl $\overline{\mathbf{O_2}}$ = potassium chlor*ite.*

K $\overline{\mathbf{ClO_3}}$ = potassium chlor*ate.*

K $\overline{\mathbf{ClO_4}}$ = potassium *per*-chlor*ate.*

As in binaries, the *hypo-* and *per-*ternaries are very few and will trouble the student very little. The **ite** compounds are also few in comparison with the **ate.** This will be a good rule for beginners: *"Call every ternary an* **ate,** *unless you have reason to call it an ite."*

Name the following:—

$H_3\overline{PO_4} = ?$
$K\,\overline{NO_3} =$
$Ca\,2\,\overline{HO} =$

$Mg\,\overline{SO_4} =$ } Which is the *ate* and which the *ite* compound?
$Mg\,\overline{SO_3} =$ }
$Ca_3\,2\,\overline{PO_4} =$

CHAPTER X.

There are three great classes of ternaries, with which the scholar should early become familiar, viz.:—**acids, bases,** and **salts.**

Acids are generally **sour,** and turn *blue* vegetable colors (such as litmus) **red.**

Bases (those that are soluble in water are called **alkalies**) turn *red* litmus paper **blue.**

Acids and bases are chemical opposites. They attack and destroy each other, forming **salts** (and water). This power of forming a *salt* with its opposites is the true test for an acid or a base. The test with litmus paper is a very good one and usually answers.

NOTE.—The pupil should here test a number of acids and bases with litmus paper. Of course, acids, bases, and salts may exist in either of the *three* physical states: solid, liquid, or gaseous. Solid or gaseous acids and bases must be dissolved in water before testing, or the litmus paper wet (which is the same thing).

Acids, bases, and salts are said to be formed on the **water-type,** thus:—

| H O H | = a molecule of water.

| A **negative** element OH | = a molecule of an acid.

| A **positive** element OH | = a molecule of a base.

| A **positive** element O a **negative** element | = a molecule of a salt.

In the above *water type*, by a negative element is meant one **negative to hydrogen**, and by a positive element one **positive to hydrogen.**

In the Reference Table, if the element is above hydrogen, it is *negative* in forming acids, bases, or salts; if below hydrogen, it is *positive.*

Write the name of the following, and mark as acid, base, or salt. (Consult Table).

$\overset{+}{K}\overline{\underline{Cl O_3}}$ = potassium chlorate = salt.

$H_2\overline{\underline{S O_4}}$ = hydrogen sulphate = acid.

$\overset{+}{Ca}\,2\,HO$ = calcium hydrate = base.

$Na_2\,\overline{SO_4}$ = ? $Na\,\overline{HO}$ =

$H\,\overline{NO_3}$ = $Mg_3\,2\,\overline{PO_4}$ =

$K\,\overline{NO_3}$ = $Na\,\overline{Cl O_3}$ =

NOTE.—The division into *positive* and *negative* elements is not always made at hydrogen. Thus, zinc is *usually* positive in forming by the *water type*, and $\overset{+}{Zn}\,2\,\overline{HO}$ zinc hydrate=base,—but *rarely*, when in presence of a stronger positive element, as potassium: $\overset{+}{Zn}\,2\,HO$ zinc hydrate becomes $H_2\,\overline{Zn O_2}$ = hydrogen zincate = an acid; and we have the salt $\overset{+}{K}_2\,\overline{Zn O_2}$ = potassium zincate. So chromium *usually* by the water

type acts as a negative element, and $H_2\overline{CrO_4}$ = hydrogen chromate = an acid, but rarely chromium acts as a positive element, and we have $\overset{+}{Cr_2}\,6\,\overline{HO}$ = chromium hydrate = a base. The pupil at this stage, however, should not attempt to deal with exceptions, but should treat the *rule* given as though it were absolute, and should consider all elements above hydrogen as negative and all elements below hydrogen as positive in the formation of acids, bases, and salts. After deciding from the formula, test all acids and bases by litmus paper, and thus prove the rule. This water type should be so thoroughly mastered, that, having the Reference Table before you, you can tell at a glance, on seeing the formula, whether the ternary is an acid, base, or salt.

CHAPTER XI.

It will be noticed that in the Reference Table four negative elements and one compound radical are linked together. These elements are called the **haloid elements** (or halogens = salt-forming), because they form salts (and acids) *without oxygen, i. e.*, they form **binary salts and acids.**

EXAMPLE.

$H\overline{Cl}$ = hydrogen chloride = a binary acid.

$\overset{+}{Mg}\overset{-}{Cl_2}$ = magnesium chloride = a binary salt.

These salts and acids may be referred to the water type by counting in the missing oxygen, thus $H\overline{Cl}$ = **hydrogen, a neg.** and the missing **O** = an acid.

Write the name, and mark as acid, base, or salt, the following:—

$\overset{+}{K_2}\overset{-}{SO_4}$ = potassium sulphate = salt.

$\overset{+}{K}\overset{-}{CN}$ = potassium cyanide = binary salt.

$\overset{+}{H_4N}\overset{-}{NO_3}$ = ammonium nitrate = salt.

HI = ?	$Mg\,2\,CN$ =
K_2CO_3 =	$Ba\,2\,ClO_3$ =
H_4NHO =	H_2SO_3 =
$Mg_3\,2\,PO_4$ =	$Mg\,SO_4$ =

CHAPTER XII.

The following **Reference Table No. 2** will be found a great aid in writing formulas of ternaries. It is to be used in connection with Table No. 1, the negative "**groupings**" in No. 2 being used with the positive (to **H**) elements in No. 1, and the positive groupings (all radicals) of No. 2 with either the negative elements of No. 1, or the negative groupings of No. 2. The positive groupings in No. 2 being radicals, unite with a single element to form a *binary*, while the negative groupings in No. 2 not being radicals (in the same sense), unite with a single element to form a *ternary*.

EXAMPLE.

$(C_2H_5)_2O$ = ethyl ox*ide* (common ether) = a binary; but

$MgCO_3$ = magnesium carbon*ate* = a ternary; and

KHO = potassium hydr*ate* = a ternary.

NOTE.—**H**, united with the hydrate grouping, gives HHO or H_2O = hydrogen oxide, a binary. The grouping HO is often considered a compound radical (hydroxyl) and its compound with an element is sometimes named as a binary. Ex: KHO = potassium hydroxide, instead of as in third example above.

REFERENCE TABLE, No. 2.

GROUPINGS.

	NEGATIVE.	POSITIVE.
UNIVALENT OR MONAD.	$\overline{HO}$ = hydrate	(Radicals.)
	$\overline{NO_3}$ = nitrate	$\overline{H_4N}$ = ammonium
	$\overline{ClO_3}$ = chlorate	$\overline{C_2H_5}$ = ethyl
	$\overline{C_2H_3O_2}$ = acetate	$\overline{C_6H_5}$ = phenyl
	$\overline{C_{18}H_{35}O_2}$ = stearate (in fats)	$\overline{CH_3}$ = methyl
	$\overline{C_{16}H_{31}O_2}$ = palmitate (in fats)	$\overline{C_5H_{11}}$ = amyl
	$\overline{C_{18}H_{33}O_2}$ = oleate (in fats)	
BIVALENT OR DYAD.	$\overline{SO_4}$ = sulphate	
	$\overline{SO_3}$ = sulphite	
	$\overline{CO_3}$ = carbonate	
	$\overline{C_2O_4}$ = oxalate	
	$\overline{C_4H_4O_6}$ = tartrate	
	$\overline{CrO_4}$ = chromate	
	$\overline{SeO_4}$ = selenate	
TRIVALENT OR TRIAD.	$\overline{PO_4}$ = phosphate	$\overline{C_3H_5}$ = glyceryl (in fats)
	$\overline{AsO_4}$ = arsenate	
	$\overline{AsO_3}$ = arsenite	
	$\overline{SbO_4}$ = antimonate	
	$\overline{BO_3}$ = borate	
	$\overline{C_6H_5O_7}$ = citrate	
Quadrivalent or Tetrad.	$\overline{SiO_4}$ = silicate	
	$\overline{P_2O_7}$ = pyrophosphate	

It has probably been noticed that in the examples given in the previous chapters, all *hydrates* contain $\overline{HO}$, which acts as a monad with reference to the elements that go with it, also, that all sulphates contain the dyad grouping $\overline{SO_4}$.

To write the formula of any substance, whose *name* is given, as potassium carbonate, we first find the carbonate grouping in Table No. 2, and write it thus, $\overline{CO_3}''$, indicating for convenience its strength by the *two* marks above. In Table No. 1 we find K has a strength of *one*; placing this before the carbonate grouping, we have $K'\overline{CO_3}''$. But it takes two monads to match one dyad, therefore we must multiply K by two, and we have $K_2\overline{CO_3}$ for the formula required.

Write the formula for magnesium phosphate;

$$\text{phosphate grouping} = \overline{PO_4}'''$$
$$\text{magnesium} = Mg'';$$

As it takes *three* dyads to match *two* triads, we have $Mg_3\,2\,\overline{PO_4}$ for the required formula.

NOTE.—The above Table contains only the most common groupings. There are phosphate groupings other than the two mentioned; also other borate, sulphate, and silicate groupings, etc. For rarer groupings see "Table No. 2, continued." The number of radicals, both negative and positive, is countless.

CHAPTER XIII.

Write formulas for the following, and mark as *acid*, *base*, or *salt*:—

potassium arsenate = $K_3\overline{AsO_4}$ = salt.
calcium acetate = $Ca\,2\,\overline{C_2H_3O_2}$ = salt.
hydrogen nitrate = $H\overline{NO_3}$ = acid.
magnesium hydrate = $Mg\,2\,\overline{HO}$ = base.

hydrogen silicate =	calcium phosphate =
calcium oxalate =	lead chromate =
sodium carbonate =	potassium arsenate =
calcium phosphate =	ethyl hydrate (common ether) =
hydrogen acetate =	ammonium oxalate =
sodium hydrate =	hydrogen tartrate =
sodium carbonate =	glyceryl hydrate (glycerine) =
magnesium phosphate =	barium nitrate =
hydrogen citrate =	silver arsenite =

As there is in acids but one element unknown (or variable), the acids are often called by *pet* names, using this element as an adjective; thus,

$H\overline{NO_3}$ = nitr*ic* acid, instead of hydrogen nitrate.
$H_2\overline{SO_4}$ = sulphur*ic* acid, instead of hydrogen sulph*ate*.
$H_2\overline{SO_3}$ = sulphur*ous* acid, instead of hydrogen sulphite.

In the *pet* name of binary acids both elements are used; as HCl = hydrochloric acid (or chlorohydric), instead of hydrogen chloride. (HCl has still another pet name used in commerce, a commercial name, muriatic acid). As you should not call a stranger by his pet name, so it is much better for you not to call any chemical compound by its pet name till you know its composition thoroughly and its chemical (systematic) name.

Most chemical compounds have one or more pet names, used in commerce, by miners, by workmen in the arts, by mineralogists, or by pharmacists. In works on chemistry, these names are often inserted after the chemical name (or *vice versa*).

If the molecular composition of the acids has been mastered, they may be called by their pet names hereafter.

Write formulas for the following:—

phosphoric acid	acetic acid
chromic acid	boracic acid
citric acid	pyrophosphoric acid
hydrofluoric acid	nitr*ous* acid (grouping $\overline{NO_2}$)

Inspection of the following questions will show that the methods of solution are the same, whether the compound is a binary or a ternary.

1. In 580 kgs. of the iron ore, ferrous carbonate ($Fe\,\overline{CO_3}$ spathic iron), how much iron?

$Fe = 56$ at. wt. $\quad 116\ Fe\,\overline{CO_3} = 56\ Fe$

$C = 12$ " $\quad 1$ " $= \frac{1}{116}$ of $56\ Fe$,

$O_3 = 48$ " $\quad 580$ kgs. " $= \frac{580}{116}$ of 56 kgs. Fe; $=$

$\overline{Fe\,\overline{CO_3} = 116}$ mol. wt. $\quad 280$ kgs.—*Ans.*

2. How much zinc sulphate could be made from 130 kgs. of Zn?

$Zn = 65 \quad 65\ Zn = 161\ Zn\,\overline{SO_4}$

$S = 32 \quad 1\ Zn = \frac{1}{65}$ of $161\ Zn\,\overline{SO_4}$

$O_4 = 64 \quad 130$ kgs. $Zn = \frac{130}{65}$ of 161 kgs. $Zn\,\overline{SO_4} =$

$\overline{Zn\,\overline{SO_4} = 161} \quad 322$ kgs.—*Ans.*

3. In 100 kgs. of potassium arsenate how much arsenicum?

4. In 150 gms. of mercur*ic* (Hg = dyad) nitrate, how much mercury?

5. In 75 gms. of mercur*ous* (Hg_2 = dyad) nitrate, how much mercury?

6. How much lead carbonate (white lead) could be made from 50 kgs. of lead?

CHAPTER XIV.

We have seen that chemical changes are called **reactions**. There are various classes of reactions, of which the simpler should be thoroughly mastered by beginners, and the more complex at several times.

[Class 1]

Reactions by **Direct Union** or **Separation**.

Fig. 1

EXPERIMENT 1.—Heat a small quantity of sulphur well mixed with copper filings in a test tube of hard glass: a reaction takes place and copper sulphide is formed.

Equation. $\underset{\text{copper}}{\text{Cu}} + \underset{\text{sulphur}}{\text{S}} = \underset{\text{copper sulphide}}{\text{CuS}}$ as our reaction.

EXP. 2.—Burn a small piece of magnesium ribbon in the air: the oxygen of the air unites with the magnesium, forming magnesium oxide.

Equation. $\underset{\text{magnesium}}{\text{Mg}} + \underset{\text{oxygen}}{\text{O}} = \underset{\text{magnesium oxide}}{\text{MgO}}$

1. How much **MgO** would be made by burning 30 grms. of **Mg**?
2. If you make 8 grms. of **MgO**, how much **Mg** must you take?

Air is composed of 1 vol. part by volume of the gas oxygen and about 4 vol. parts by volume of the gas nitrogen,

(with traces of carbonic oxide and vapor of water, etc.) Burning, or **combustion,** is in general, the *rapid* union of a substance with oxygen. The temperature at which the substance takes fire, *i. e.*, unites *rapidly* with the oxygen of the air; is called the **igniting point.** Of course, the product of the burning will be **an oxide.**

EXP. 3.—Burn some sulphur in a bottle containing a small quantity of water;

Reaction (a): $S + O_2 = \underset{\text{(a gas)}}{SO_2}$

Close the mouth of the bottle and shake;

Reaction (b): $SO_2 + H_2O = H_2\overline{SO_3}$ (an acid).

Test for the acid by litmus paper.

EXP. 4.—Scrape some fine powder from a piece of quicklime into a test tube of water;

Reaction: $\underset{\text{quicklime}}{CaO} + H_2O = \underset{\text{water slacked lime}}{Ca\,2\overline{HO}}$ (a base).

Test for the base by litmus paper.

The last two reactions reveal the fact that there are different kinds of *oxides.*

The two principal classes of oxides are:—

1. **Acid-forming oxides.**
2. **Basic oxides.**

The first are oxides of negative elements and they unite *directly* with water to form acids, as in reaction (b) of EXP. 3.

The second are oxides of positive elements (metals) and unite directly with water to form bases, as in reaction of EXP. 4.

Acid-forming oxides are often called **anhydrides** (without water), since they may be considered as acids deprived of water.

EXAMPLE.

SO_2 = sulphur*ous* anhydride.

(The older chemists called the anhydride the acid, as SO_2 = sulphur*ous* acid, but this is not now correct usage).

Basic oxides are often called **bases**. (It is important to know that this is still correct usage. Indeed, some authors give as the definition, "A base is a metallic oxide," and these authors call the true base a "hydrated oxide" or "hydrated base"). Basic oxides unite with acids to form salts, just as the true bases do, and by a reaction very similar.

It will be seen that the term "base" is used by chemists somewhat indefinitely. In a wide sense it is used of any substance that will unite with an acid to form a salt (or a salt and water, or a salt with *free* hydrogen, etc.) In this wide sense it would include:—

1. Positive elements (or groupings).
2. Basic oxides.
3. Positive hydrates.

The word "base" has been thus far used in this last and restricted sense. The word "alkali" is also used in a comprehensive sense. The sense of the words, however, may easily be told from the connection.

CHAPTER XV.

Class 2.

Reaction by **Change of Partners**.

Exp. 5.—Dissolve one gram of sodium chloride (common salt) in nine grams of (distilled) water (a ten per cent. solution). Dissolve one gram of silver nitrate (lunar caustic) in nineteen grams of water (a five per cent. solution). Pour a little of the first solution into a small test-tube, and into it let fall a few drops taken from the second, by means of a glass tube dipped beneath the solution and closed at the opposite end by the finger. A beautiful, white, curdy solid (silver chloride) is formed by the reaction, and slowly settles to the bottom of the test tube.

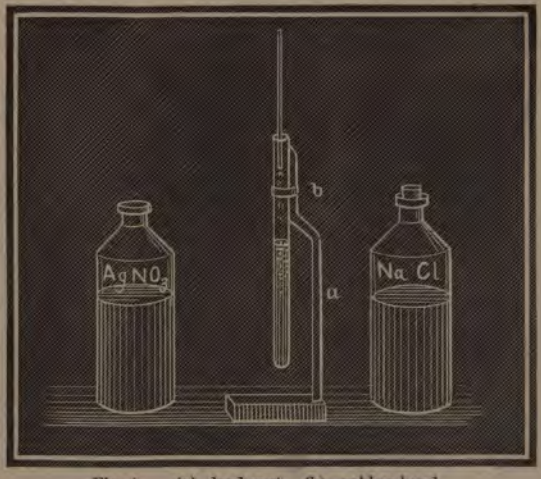


Fig. 4. (a)—lead post. (b)—rubber band.

Taking this reaction as the type of its class, we may learn much from it.

Just as by change of partners,

$$\left\{\begin{matrix}\text{George}\\ \text{Lucy}\end{matrix}\right\} \overset{\text{and}}{+} \left\{\begin{matrix}\text{Charles}\\ \text{Emma}\end{matrix}\right\} \overset{\text{become}}{=} \left\{\begin{matrix}\text{George}\\ \text{Emma}\end{matrix}\right\} \overset{\text{and}}{+} \left\{\begin{matrix}\text{Charles}\\ \text{Lucy}\end{matrix}\right\}$$

so

$$\underset{\substack{\text{sodium}\\ \text{chloride}}}{NaCl} + \underset{\substack{\text{silver}\\ \text{nitrate}}}{AgNO_3} = \underset{\substack{\text{sodium}\\ \text{nitrate}}}{NaNO_3} + \underset{\substack{\text{silver}\\ \text{chloride}}}{AgCl}$$

Soluble solid and therefore not precipitated, but remaining in solution.

Insoluble solid, called a *precipitate*.

NOTE.—This is a very simple and frequent method of reaction. **Filter, wash, and preserve all precipitates for future use in experiments, or as samples of the various compounds (see EXP. 6). Carefully label the vials in which precipitates are preserved. It will be noticed that Ag Cl** *turns dark* when exposed to the light (see silver).

Water favors chemical change.

(There are exceptions.—Water does not favor ordinary combustion). Thus, two substances in solution will react with each other, which would not, if they were mixed dry. Iron rusts (unites slowly with the oxygen of the air, forming ferric oxide Fe_2O_3) if exposed to the air wet. Knives and forks must be wiped dry, else they rust. **Solution** divides a substance more minutely and evenly than can be done by any other method of mechanical division. Solution separates the molecules. For instance, if a teaspoonful of common salt be thrown into a barrel of water and dissolved, molecules of salt may be found in every drop of the entire barrel. They seem to move among the molecules of water freely, the water giving them an atmosphere in which they easily perform reactions with other substances. The water is not written in the reaction, unless it really takes some part in the atomic changes.

When a substance dissolves in water, and unites chemically with the water to form another compound (as in reactions of EXP. 3 and 4), this is not a mere solution, but something more. In a *mere* solution the substance goes into the water (somewhat as grains of sand might be poured into a measure of peas) without uniting with the molecules of water at all.

A gas, as we have already learned, may be dissolved in water as well as a solid.

A liquid may also be dissolved in water, but we speak of the liquid not as dissolved in water, but as *diluted with water* (or mixed) and we do not speak of the resulting liquid as a solution (see OILS).

When as much as possible of the substance is dissolved in a certain amount of water, the solution is said to be a **saturated solution.**

Many solids and gases are insoluble in water. (Some liquids will not mix with water and therefore cannot be diluted). Often these may be dissolved in other liquids, as alcohol (ethyl hydrate), hydrochloric acid, etc. The liquid dissolving the substance is called a **solvent.**

Whenever two substances, one at least being in solution, react, forming a solid insoluble in the liquid, the resulting solid, as it usually quickly falls to the bottom, is appropriately called a **precipitate.** If soluble solids are formed at the same time, they of course remain in solution. If gases are formed in the reaction, they come off from the liquid in bubbles. Substances which react with each other as in the above reaction, especially those that are much used in the chemical laboratory, are called **reagents.**

EXP. 6.—Into a test-tube containing silver nitrate solution let fall a few drops of hydrochloric acid. The chemicals react by change of partners, as in EXP. 5, thus:—

Reaction: $\underset{\text{hydrogen chloride}}{\mathbf{HCl}} + \underset{\text{silver nitrate}}{\mathbf{Ag\overline{NO_3}}} = \underset{\text{hydrogen nitrate}}{\mathbf{H\overline{NO_3}}} + \underset{\text{silver chloride (precipitate)}}{\mathbf{AgCl}}$

Precipitates may be separated from the liquid by **filtration.** Cut and fold some filter paper, thus:—

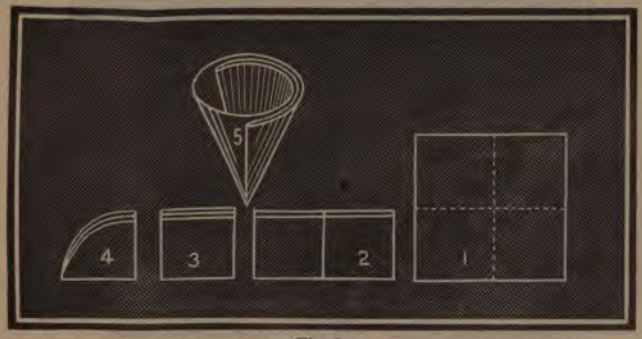


Fig. 5.

and place it on a funnel (tunnel), pouring the contents of the test tube upon it.

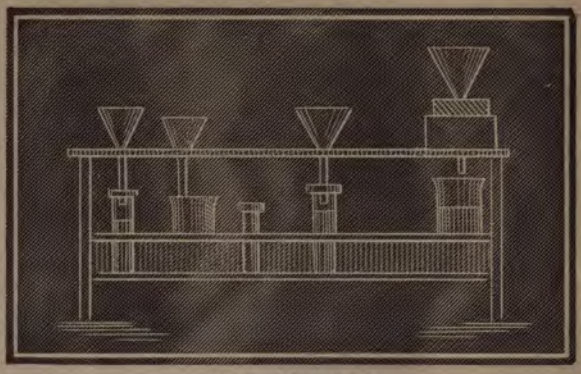


Fig. 6.—Filter stand.

The precipitate remains upon the filter, while the liquid called **filtrate** (by workmen in the arts often called **mother liquor**), passes through. Wash the precipitate, to free it entirely from the filtrate, by forcing with the breath water in fine spray from wash bottles upon it. Remove the precipitate and dry upon glass, or dry before removing, as is sometimes more convenient.

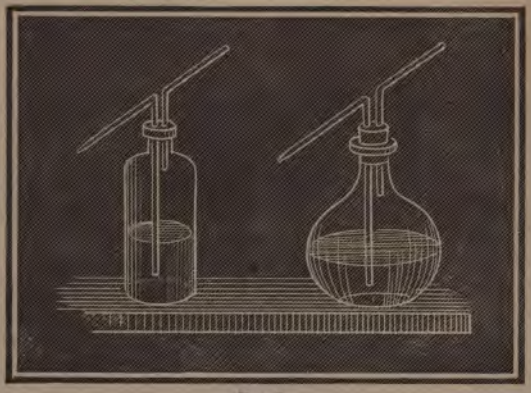


Fig. 7.

Bottle for cold water. Flask for hot water.

CHAPTER XVI.

CLASS 2. (continued).

EXP. 7.—Place ferr*ous* sulphide (previously washed by standing over night in water) in a small flask, and pour upon it dilute sulphuric acid.

Reaction: $FeS + H_2\overline{SO_4} = Fe\overline{SO_4} + H_2S$

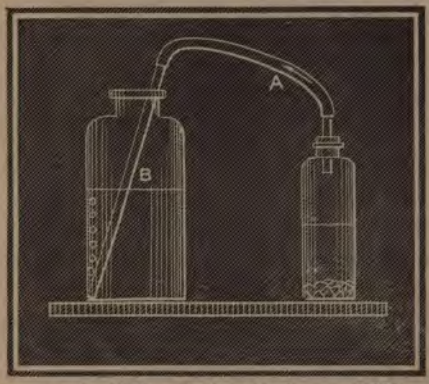


Fig. 8.—Making solution of hydrogen sulphide.

As H_2S is a gas, it comes off in bubbles. Close the mouth of the flask by a rubber cork, through which a fine, glass tube passes. By means of a rubber tube allow the gas to pass into water. As the gas is soluble (*three* volumes in one of water), we have a solution of the gas. Set this aside as a *reagent*.

Caution.—H_2S is a very poisonous gas, and EXP. 7 should be performed under a gas chimney, or near a window with an *outward* draft. (To breathe a *very small* quantity mixed with air will, however, do no harm). This gas is largely used in the laboratory, and chemists are often more careless with it than is consistent with health. Learn to be *cautious* and *careful* in performing all experiments, *following directions minutely*.

EXP. 8.—To a solution of lead acetate in test tube add drop by drop solution of H_2S.

Reaction: $Pb\,2\overline{C_2H_3O_2} + H_2S = PbS + 2H\overline{C_2H_3O_2}$

(lead acetate; hydrogen sulphide; lead sulphide (black precipitate); hydrogen acetate)

It will be noticed, that when the hydrogen changes partners with

the lead atom and takes the acetate grouping, the hydrogen and acetate grouping being univalent, they are matched *one* to *one*, giving us two molecules of acetic acid. It would be incorrect to write $H_2 2\overline{C_2H_3O_2}$. Never put *two* monads with *two* monads in reactions, but always *one* monad with *one* monad, and if there be two of each, double the molecule.

Just as we must take *two* monads to match *one* dyad in a binary, so we must take *two* molecules containing monad partners to react with *one* molecule containing dyad partners. Reagents are hereafter presumed to be in solution.

EXP. 9.—To mercuric chloride (corrosive sublimate) add drop by drop potassium iodide.

Reaction: $\underset{\text{mercuric chloride}}{HgCl_2} + \underset{\text{potassium iodide}}{2KI} = \underset{\text{mercuric iodide (red precipitate)}}{HgI_2} + \underset{\text{potassium chloride}}{2KCl}$

If too little is added, the precipitate dissolves; if too much is added, the precipitate dissolves, *i. e.* the precipitate dissolves in **excess** of either reagent. Notice that the molecule of mercuric chloride contains *dyad* partners (**Hg** = a dyad, and Cl_2 two monads = a dyad), while potassium iodide contains *monad* partners; therefore, we must take *two* molecules of the latter to react with *one* of the former.

EXP. 10.—Into a solution of arsen*ous* oxide let fall a few drops of dilute hydrochloric acid.

Reaction (a): $As_2O_3 + 6HCl = 2AsCl_3 + 3H_2O$

As_2O_3, a molecule containing hexad partners, requires *six* molecules of **H Cl** to react with it. $AsCl_3$, arsenous chloride, being soluble in water, does not appear as a precipitate. Into the test tube drop solution of H_2S.

Reaction (b): $2AsCl_3 + 3H_2S = \underset{\text{(lemon yellow precipitate)}}{As_2S_3} + 6HCl$

In reaction (b) we must take *two* molecules containing triad partners ($AsCl_3$) to react with *three* molecules containing *dyad* partners (H_2S), just as we take *two* triad elements to match *three* dyad elements in forming binaries. In the second member of the equation we must be careful to match the atoms according to their "strength" and to multiply the molecules *afterward*, so that the number of atoms of any element shall be the same in both members.

EXP. 11.—To lead acetate (sugar of lead) add magnesium sulphate.

Reaction: $Pb\overline{2C_2H_3O_2}$ + $Mg\overline{SO_4}$ = $Pb\overline{SO_4}$ + $Mg\overline{2C_2H_3O_2}$
(a poison; its antidote; insoluble and therefore harmless. (white precipitate); soluble, but harmless salt.)

Inspection of this last reaction will reveal the exact nature of a *chemical* antidote. Let the test tube represent the stomach. A **chemical antidote** is a substance, which will unite with the poison, forming insoluble or harmless compounds, or both (see chap. xxxviii).

EXP. 12.—To calcium hydrate (lime water) add ammonium carbonate.

Reaction: $Ca\,2\overline{HO} + (\overline{H_4N})_2\overline{CO_3} = Ca\overline{CO_3} + 2\overline{H_4N}\,\overline{HO}$
(white precipitate (chalk))

Inspection of the following questions and the method of solving them will open to the attentive student a wide field for careful and accurate work. To such a student the problems are not difficult.

1. From 542 mgs. of mercuric chloride, how much mercuric iodide could be made by adding potassium iodide?

Reaction: $Hg\,Cl_2 + 2\,K\,I = Hg\,I_2 + 2\,K\,Cl$

200	200
71	254
271 mol. wt.	454 mol. wt.

271 mgs. $Hg\,Cl_2$ (will make) 454 mgs. $Hg\,I_2$

1 " " = $\frac{2}{7}\frac{1}{1}$ of 454 $Hg\,I_2$

542 " " = $\frac{5}{2}\frac{4}{7}\frac{2}{1}$ of 454 mgs. HgI_2 = 908 mgs.—*Ans.*

2. How much mercuric chloride will be required to make 150 gms. of mercuric iodide (adding **K I**)?

Reaction: $Hg\,Cl_2 + 2\,K\,I = Hg\,I_2 + 2\,K\,Cl$

200	200
71	254
271	454

454 $Hg\,I_2$ (would require) = 271 $Hg\,Cl_2$

1 " = $\frac{1}{4\,5\,4}$ of 271 $Hg\,Cl_2$

150 gms. " = $\frac{1\,5\,0}{4\,5\,4}$ of 271 gms. " = $89\frac{1\,2\,2}{2\,2\,7}$ gms.—*Ans.*

3. How much potassium iodide would be required to make 227 gms. of $Hg\,I_2$? *Ans.* 166 gms.

4. How much potassium chloride could be made by using 996 gms. of potassium iodide? *Ans.* 447 gms.

CHAPTER XVII.

CLASS 3.

Reaction of **Acid** and **Base**.

When an *acid* and *base* are united, the result is a **salt** and **water**. The acid is said to *neutralize* the base (or *vice versa*).

EXP. 13.—To barium hydrate add drop by drop sulphuric acid.

Reaction: $\underset{\text{base}}{Ba\,2\overline{HO}} + \underset{\text{acid}}{H_2\overline{SO_4}} = \underset{\substack{\text{salt}\\\text{(white precipitate)}}}{Ba\overline{SO_4}} + \underset{\text{water}}{2\,H_2O}$

EXP. 14.—To oxalic acid add calcium hydrate.

Reaction: $\underset{\text{acid}}{H_2\overline{C_2O_4}} + \underset{\text{base}}{Ca\,2\overline{HO}} = \underset{\substack{\text{salt}\\\text{(white precipitate)}}}{Ca\overline{C_2O_4}} + \underset{\text{water}}{2\,H_2O}$

EXP. 15.—To sodium hydrate add drop by drop acetic acid, till solution is neutral to litmus paper.

Reaction: $\underset{\text{base}}{Na\overline{HO}} + \underset{\text{acid}}{H\overline{C_2H_3O_2}} = \underset{\text{salt}}{Na\overline{C_2H_3O_2}} + \underset{\text{water}}{H_2O}$

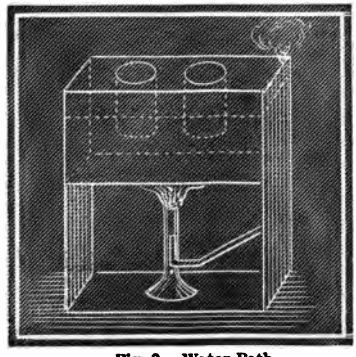


Fig. 9.—Water Bath.

There is no precipitate, because sodium acetate is soluble in water.

Filter to remove any slight solid impurities and evaporate to dryness in evaporating dish (or beaker) over a **water bath**. (See Fig. 9). Sodium acetate, a solid, remains.

CLASS 3 is only another form of CLASS 2. In reactions of CLASS 3 the same law holds good, viz.: "that *two* molecules containing monad partners must be taken to react with *one* molecule containing *dyad* partners, etc."

CLASS 4.

Reactions of **Acids** and **Carbonates**.

In these reactions, the carbonate grouping breaks up. When an *acid* unites with a *carbonate*, the result is a **salt, water,** and **carbonic oxide** (a gas). The law in regard to molecules containing partners of different strengths holds good, as in the last two cases. This reaction is frequently used by the druggist and pharmacist.

EXP. 16.—To acetic acid add sodium carbonate (solid or in solution) till effervescence ceases. (**Effervescence** is the bubbling caused by the rapid separation of a gas from a liquid).

Reaction: $\underset{\text{carbonate}}{Na_2\overline{CO_3}} + 2H\overline{C_2H_3O_2} = \underset{\substack{\text{salt}\\(\text{soluble})}}{2Na\overline{C_2H_3O_2}} + \underset{\text{water}}{H_2O} + \underset{\text{carbonic oxide}}{CO_2}\uparrow$

Filter, evaporate filtrate, and preserve. The salt is obtained as in EXP. 15. The heat of evaporation entirely expels any CO_2 that may be held in solution after the reaction.

EXP. 17.—Into dilute citric acid let fall calcium carbonate till effervescence ceases. Filter, evaporate, and preserve as before.

Reaction: $\underset{\text{carbonate}}{3Ca\overline{CO_3}} + \underset{\text{acid}}{2H_3\overline{C_6H_5O_7}} = \underset{\text{salt}}{Ca_3 2\overline{C_6H_5O_7}} + \underset{\text{water}}{3H_2O} + \underset{\text{carbonic oxide}}{3CO_2}\uparrow$

NOTE.—*Three* molecules containing *dyad* partners ($Ca''\overline{CO_3}''$) must react with *two* molecules containing *triad* partners ($H_3'''\overline{C_6H_5O_7}'''$), as before.

Notice, in evaporating, that this salt (calcium citrate) is less soluble in *hot* than in *cold* water; an exception to the general rule, that "for equal volumes, *hot water dissolves more of a solid than cold water.*"

As a rule, "*hot water dissolves less of a gas* than an equal volume of cold water." Indeed, many gases not only will not dissolve at all in boiling water, but may be completely expelled from water, in which they may have been previously dissolved, by boiling it.

Before leaving these chapters on reactions, the student should be able to write promptly any reaction belonging to either of the four classes, provided he has the *names* of the two substances given *and the two reference tables before him.*

MISCELLANEOUS PROBLEMS.

1. Write formulas for five binary acids.
2. Write formulas for ten ternary salts.
3. Write formulas for two binary salts.
4. Write formulas for six ternary acids.
5. Write formulas for five bases.
6. In 150 gms. arsenous oxide, how much **As**?
7. In 1000 gms. of silver chloride, how much silver?
8. How much mercuric sulphide could be made by using 50 kgs. of mercury (Hg'')?
9. Reaction when phosphorus burns in air?
10. When carbon burns?

Reactions when the following are united:—

11. Stannous chloride (Sn'') and hydrogen sulphide?
12. Copper sulphate and sodium hydrate?
13. Sodium carbonate and hydrochloric acid?
14. Ammonium carbonate and calcium hydrate?
15. Potassium hydrate and sulphuric acid?
16. Calcium hydrate and citric acid?
17. Potassium *carbonate* and tartaric acid?
18. Acetic acid and magnesium *carbonate?*
19. To make 190 gms. of magnesium chloride (by adding **H Cl**), how much magnesium *carbonate* must be taken?
20. How much arsenous oxide, As_2O_3 (white arsenic) was contained in a vessel full of water, from which 15 mgs. of arsenous sulphide was precipitated (by adding **H Cl** and H_2S)?

CHAPTER XVIII.

OXYGEN.

EXP. 18.—Carefully pulverize in a mortar a small quantity of potassium chlorate, and having mixed it thoroughly with an equal bulk of *pure* manganese dioxide, introduce into a small copper retort. Heat by a strong alcohol flame, or flame from a Bunsen's burner. Collect **O** in receivers over a pneumatic tub, as represented in Fig. 10.

Reaction: $\mathbf{K\,Cl\,O_3} = \mathbf{K\,Cl} + \mathbf{O_3}$

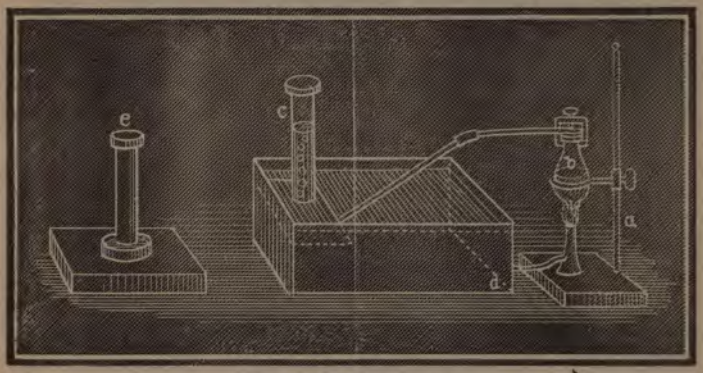


Fig. 10.—Making Oxygen.
(a)–retort stand; (b)—retort; (c)–receiver; (d)–pneumatic tub; (e)–receiver removed.

NOTE.—The presence of $\mathbf{Mn\,O_2}$ causes the **O** to come off more steadily and at a lower temperature, but as it takes no part in the reaction, it is not written. The first bubbles that come off are composed principally of air from the retort. The **O** often looks *cloudy*, because small particles of the salt and oxide are carried over by the *draft*. These gradually dissolve or settle into the water. Instead of a copper retort a glass flask placed on a sand bath (iron basin filled with sand) may be used. Three or four receivers should be inverted, and as fast as filled removed by means of a small cover, holding a little water, to prevent the escape of the gas. Small quantities of **O** may be conveniently made by using test tubes as retorts, test tubes, or bottles, as receivers, and a beaker as a pneumatic tub.

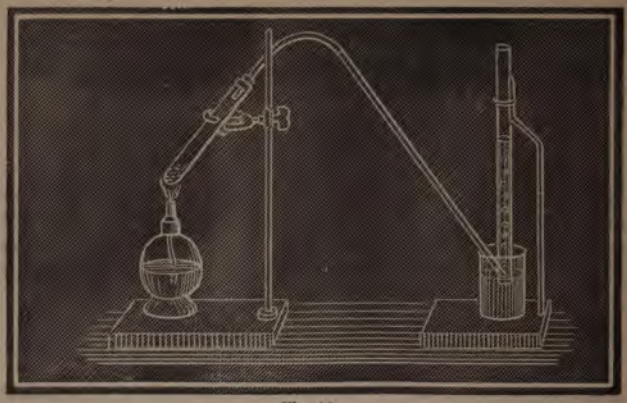


Fig. 11.

Caution.—$K\overline{ClO_3}$ must not be heated alone. Commercial MnO_2 is sometimes adulterated with carbon (pounded coal) and when mixed with $K\overline{ClO_3}$ and heated, the mixture explodes violently. The delivery tube must be removed from the water *before* the heat is taken from the retort, otherwise as the gas in the retort cools and contracts, the water is forced back along the tube by atmospheric pressure. The first that falls into the highly heated retort is instantly converted into steam, causing an explosion. Ordinary care will prevent any serious accident. The chief danger in breaking glass retorts is to the eyes.

Learn here, that an explosion is (generally) caused by the *sudden* conversion of matter from the *solid* or *liquid* to the *gaseous* state.

Oxygen is a colorless **gas,** without odor or taste. As we have inferred from the formulas thus far used, it is a *very* **abundant element.** It exists **free** (uncombined) **in the air,** forming one-fifth its volume. Chemically combined with other elements, it forms by weight eight-ninths of water, one-half of minerals, three-fourths of animal tissues, and four-fifths of vegetable tissues; in short, so far as we know, about two-thirds of the earth.

Exp. 19.—Into a receiver (bottle) of **O,** plunge a taper having a live coal upon the end, it immediately bursts into a blaze. Quickly remove and blow out the flame. Repeat the experiment from twenty to forty times, as may easily be done before the gas is exhausted.

Wood, oil, tallow, etc., (things that we ordinarily burn) are composed principally of H and C, and are therefore called **hydrocarbons**. When hydrocarbons (as the taper in the experiment) burn, two reactions take place, viz.:—

$$\left.\begin{array}{l} H_2 + O = H_2O \text{ (steam)} \\ C + O_2 = CO_2 \text{ (a gas)} \end{array}\right\} \begin{array}{l}\text{Gaseous} \\ \textit{products} \text{ of} \\ \text{the com-} \\ \text{bustion.}\end{array}$$

Immediately after the O is exhausted, pour into the receiver a very small quantity of water, and closing its mouth, shake at intervals. The CO_2 gradually dissolves.

$$\text{Reaction: } \underset{\substack{\text{acid forming}\\ \text{oxide}}}{CO_2} + H_2O = \underset{\text{acid}}{H_2\overline{CO_3}}$$

Test by litmus paper, but as $H_2\overline{CO_3}$ is a very weak acid, litmus paper must remain a little time in it.

O is a vigorous supporter of combustion. O is *heavier than air*, for we hold the mouth of the receiver upward to retain the gas.

Water is the standard of specific gravity for solids and liquids, but air for gases. Sp. gr. of air is 1, of O 1.1+. But in chemistry **hydrogen** is made the standard for gases.

EXP. 20.—Straighten a steel (**Fe**) watch spring and tip the end with a little **S** (kindling wood for the steel, as **S** has a much lower igniting point). Ignite the **S** and plunge the spring into a receiver of **O**. The steel burns brilliantly.

$$\text{Reaction: } Fe_3 + O_4 = \underset{\substack{\text{(triferric tetroxide,}\\ \text{black or magnetic}\\ \text{iron oxide)}}}{Fe_3O_4}$$

As this oxide of iron does not unite with water, the water shaken up in the receiver has no effect upon litmus paper. This reaction is an irregular one (strength of iron apparently not according to Table).

If the air were pure O undiluted with N, our iron stoves would take fire, and a general conflagration would spread over the earth. We could not, for any length of time, breathe pure O, as it would so stimulate the vital

processes as to produce speedy death. A small animal placed in a jar of constantly renewed O, dies in a few hours.

EXP. 21.—Charcoal *bark*, a small part of which has been heated to a live coal, plunged into **O** (by means of a **Cu** wire twisted about it), bursts into a vivid combustion.

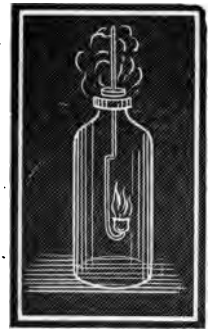


Fig. 12.

EXP. 22.—Repeat EXP. 3 in jar of **O**. (Place **S** on chalk in a combustion spoon. Copper wire twisted about a piece of chalk makes a good combustion spoon).

EXP. 23.—Cut under water, quickly and carefully dry between pieces of blotting paper, a small piece of phosphorus (not larger than a grain of wheat). Place in a combustion spoon, ignite by hot wire, while lowering into a large jar of **O**, containing at the bottom a little water. A blinding light is caused by the combustion.

Reaction: $P_2 + O_5 = \underset{\text{dense white fumes}}{P_2O_5}$

In a short time these fumes are dissolved in the water, and the following reaction slowly takes place:—

$$\underset{\text{acid forming oxide}}{P_2O_5} + 3\overline{H_2O} = 2\underset{\text{acid}}{H_3\overline{PO_4}}$$

Test by litmus paper.

Caution.—Handle **P** with great care, on no account touching it. The heat of the hand may inflame it, and its burns are dangerous. Its vapor is highly poisonous, as is also its oxide P_2O_5. The dense, white fumes should be immediately shut in by stopple attached to combustion spoon. (Fig. 12).

O is an exceedingly **active** gas. It alone supports all ordinary burning that takes place in the air. *To bring this gas in contact with the blood* is the object of respiration in animals. The blood absorbs and carries O to all the tissues, the most prominent chemical change taking place in the body being that of *oxidation*. (See EXP. 57),

There is a peculiar form of condensed O, called **Ozone.** It is O in an *allotropic* state. It may be made in various ways, especially by the action of electricity on common O. It occurs in minute quantities in the air. It is even more active than O and is a powerful **disinfectant.** In it tainted meat in a few moments loses its putrescent odor, because the foul material is oxidized, forming *relatively* wholesome compounds. The molecule of *ozone* may be represented thus $\boxed{\overset{O}{OO}}$ with *three* atoms, that of oxygen being $\boxed{OO}$ composed of *two* atoms.

CHAPTER XIX.

HYDROGEN.

EXP. 24.—Place in a small flask, or large test tube, (hydrogen generator) some granulated **Zn.** Upon it pour dilute (10 per cent.) sulphuric acid. Close mouth of flask with perforated rubber cork, through which passes a fine glass tube. Collect **H** over pneumatic tub, as in Fig. 13.

$$Zn + H_2SO_4 = ZnSO_4 + H_2\uparrow$$

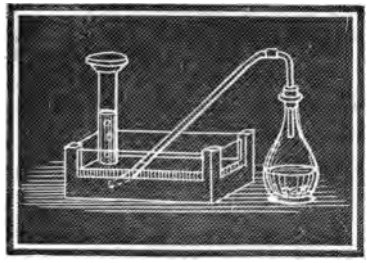


Fig. 13.—Making Hydrogen

NOTE.—Collect several receivers of the gas, and after the reaction has ceased, filter the liquid remaining in the flask; evaporate filtrate, and the white salt, zinc sulphate, is obtained. If a drop of the filtrate is placed on a piece of glass and set aside, *away from the dust,* beautiful crystals of the salt are left upon the glass.

Hydrogen is a colorless gas, without odor or taste (when *pure*). It is the essential constituent, as we have seen, **in acids.** Indeed, acids have sometimes been defined as "salts of hydrogen." H does not exist *free.* It has been condensed by cold and pressure, first, to a liquid and then to a white solid. H is not poisonous, but destroys life, just as water does, by shutting out the O. The lungs may be inflated with the *pure* gas without harm. (**Caution.**—Gases made by beginners must never be breathed. As a rule, a gas is obtained absolutely *pure* with great difficulty. For methods of obtaining gases pure see larger text-books or some treatise). Chemists take hydrogen as the standard of specific gravity for gases. With this standard, "*one-half its molecular weight is the sp. gr. of any gas.*"

EXP. 25.—Remove a jar of **H**, holding the mouth downward, and into it plunge slender lighted taper. The **H** takes fire and burns at the mouth of jar, but the taper is extinguished in the gas above. It may be relighted by the burning **H** as it is being removed.

H is **lighter than air,** for we hold the gas by keeping the mouth of the receiver downward. H is **very inflammable,** *i. e,* its igniting point is low. It **does not support combustion** (of hydrocarbons).

NOTE.—Combustible bodies and supporters of combustion are relative terms. A jet of **O** would burn in a jar of **H** just as well as a jet of **H** in a jar of **O.** One as well as the other, could be called the supporter of the combustion.

EXP. 26.—Pour **H** upward from one test tube into another, **displacing** the air. Test by igniting.

EXP. 27.—Collect **H** from generator in test tube by **displacement** of air. Test.

EXP. 28.—Attach a clay pipe (old or varnished) to generator and blow soap bubbles with **H.** They ascend and may be ignited in the air.

Hydrogen is the **lightest substance known,** being about 14½ times lighter than air.

Exp. 29.—Attempt to blow soap bubbles, using a *new* clay pipe and letting the gas come *slowly*. The **H** escapes by **diffusion** through the clay so rapidly, that the bubbles cannot be blown. Quickly substitute the *old* pipe (whose pores are closed) and the bubbles are blown without difficulty.

All gases possess power of **diffusion,** but the power is possessed by H in an extreme degree. The diffusibility of gases is *"inversely as the square roots of their densities,"* the density (or sp. gr.) of any gas being half its molecular weight.

EXAMPLE.

$$\sqrt{\frac{16}{\text{density of O}}} : \sqrt{\frac{1}{\text{density of H}}} :: \underset{\text{diffusibility of H}}{4} : \underset{\text{diffusibility of O}}{1}$$

That is, H has four times the diffusive power of O, or diffuses four times as rapidly. H may leak through vessels that would retain O permanently.

Fig. 14.—Philosopher's lamp.

Exp. 30.—Close generating flask by a rubber stopple, through which passes a *hard* glass tube, with fine opening. *After the air has been expelled by the* **H**, ignite the jet. The apparatus is the "Philosopher's Lamp." Over the flame invert a cold, dry test tube. It is bedewed with moisture.

$$H_2 + O = H_2O$$

When H burns, the **product** is water (steam). The H flame gives **little light,** but **great heat.** The alcohol (ethyl hydrate) flame gives little light and great heat, because alcohol contains much H.

The flame of the **oxy-hydrogen blowpipe** melts many substances (as platinum), infusible in ordinary fire, the alcohol flame, or the flame from a Bunsen's burner.

Fig. 15.—Section of oxy-hydrogen blowpipe.

The **H** from the gasholder is first turned on and ignited, and afterward the **O** is turned on.

Exp. 31.—Fill over a pneumatic tub a stout quart fruit jar one-third with **O**, and the remainder with **H**. *Wrap about it a cloth*; remove, and holding the mouth downward, quickly ignite by means of a taper. A sharp explosion ensues.

There are two reports heard as one, the second so closely follows the first. The first is caused by the sudden (but not greater than a few volumes) expansion of the gases heated by their union; the second is caused by (the steam suddenly condensing) the rush of the air from all sides to fill the partial vacuum. **Caution.**—Of course, **H** explodes when mixed with air. Care must be taken to expel all air from apparatus before igniting jets of **H**. Never ignite large quantities of the gas.

Exp. 32.—Repeat the experiment of decomposing water as explained in connection with Fig. 1.

This proves by **Analysis** the composition of water. If we explode *two* volumes of **H** with *one* of **O** and find we have nothing but water left, we prove the composition of water by **Synthesis.**

Water H_2O

The wonderful power of **chemical affinity** is shown in this compound. A union of the most inflammable substance known, with the most vigorous supporter of combustion,—forms another substance used to extinguish fires. We have called this substance by its pet name, because it is so common a substance and so generally distributed. Its systematic name (hydrogen oxide) is seldom used. We

have already learned that **water** is the general **solvent** in nature, dissolving most gases and solids and diluting most liquids.

Hard water contains minerals in solution; soft water does not.

Hardness produced by earthy (**Ca. Mg.** Sr. Ba. etc.) carbonates is called **"temporary hardness,"** because the carbonate may be precipitated by boiling, leaving the water soft.

EXP. 33.—Expose on a deep plate in the school-room for 24 hours distilled (soft) water. Carbonic oxide (CO_2) from the air dissolves in it. Shake up with this water a considerable quantity of finely pulverized marble ($CaCO_3$). Filter. The filtrate is water of **"temporary hardness."** (Carbonates dissolve in water containing CO_2, but not in pure water). Boil in a deep beaker. The CO_2 is driven off, and a white precipitate of $CaCO_3$ falls. The "fur" upon the *teakettle* is a precipitated carbonate.

Hardness produced by earthy sulphates is called **"permanent hardness,"** because the water cannot be made soft by boiling. (See SOAP).

The water held in suspension by the atmosphere is essential, not only to plant life, but to animal life as well. The earth would be a vast desert, were it not that tons of water are constantly being carried up from the ocean by **evaporation,** so that the air currents may distribute it, not alone to fall as rain, but also to keep the atmosphere everywhere moist.

Many substances, when they crystallize (assume a symmetrical shape in solidifying), take up a definite amount of water, called **water of crystallization.** This may be expelled by heat, but the *essential* properties of the substance are not changed.

EXP. 34.—Heat in a porcelain dish crystals of copper sulphate previously carefully weighed; the **water of crystallization** is expelled

and the blue color disappears. Weigh the sulphate. It has lost over one-third its weight, as the formula of *crystallized* copper sulphate is $CuSO_4$, $5H_2O$. Touch with a drop of water, the color returns. Dissolve in a small quantity of water, evaporate slightly, and set aside to cool. Beautiful **crystals** of copper sulphate form as the solution cools.

Fine **crystals** of various substances may be formed in this way, viz., by making saturated solution of the substance, slightly evaporating and setting aside for a few days. Making a collection of **crystals** will be found a very profitable exercise.

Water of crystallization is not written in ordinary reactions of substances in solution, but must be taken into account in dealing with the dry solids. Of course, a larger quantity of the crystallized solid must be taken to equal a smaller quantity of the uncrystallized, *if the solid takes up water of crystallization.*

Some substances, such as sodium acetate ($NaC_2H_3O_2$, $3H_2O$), sodium carbonate (Na_2CO_3, $10H_2O$), etc., when exposed to the air, lose their water of crystallization and crumble to powder. These are said to be **efflorescent.**

Some substances, as potassium carbonate (K_2CO_3), when exposed to the air, absorb moisture and dissolve (or partially dissolve). These are said to be **deliquescent.**

The law of physics, that "heat expands and cold contracts" does not hold with water in cooling from about 4° (C) to 0°, through which space it steadily expands, until it freezes (crystallizes) at 0°. The importance of this exception cannot be over-estimated, for it makes *ice lighter than water*, and so prevents lakes and rivers from freezing solid.

Water, containing impurities in solution, may be purified by **distillation.** The water is placed in a **retort,** or "**still,**" is heated, rises as steam (at 100°), which, passing through the **condenser,** (supplied with cold water in direction of arrows, Fig. 16), condenses, and is collected in

a receiver. Steam (**"dry steam"**) is an invisible gas. That which is seen and often miscalled steam, is steam condensed (or partially condensed) into minute globules of water and held in **suspension** (like dust) by the air (or by the invisible steam, in which case the steam is called **"wet steam"**).

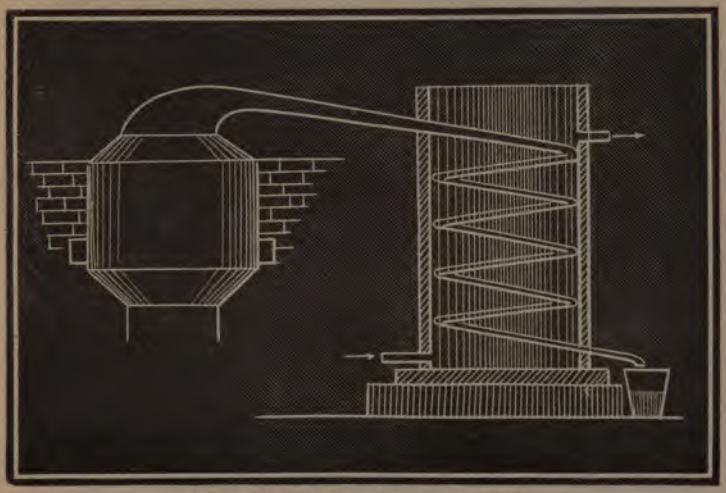


Fig. 16.—Retort, or "still," and condenser.
⟶ Current of cold water. ⟶

CHAPTER XX.

NITROGEN.

Exp. 35.—Place a piece of chalk on a tripod wire-holder, standing in a deep plate of water. Upon the chalk place a small piece of **P**. Ignite by hot wire and quickly invert a receiver over it.

$$P_2 + O_5 = \underset{\text{soluble white fumes}}{P_2O_5}$$

Fig. 17.—Making nitrogen.

The **P** unites with the **O** in the jar. The phosphoric oxide dissolves and the water rises by atmospheric pressure and fills one-fifth of the receiver, the space before occupied by the **O**. **N** remains in the receiver above the water. Leave over night, that the small quantity of **O** left, when the flame of **P** is extinguished, may unite with the remaining **P**. Of course, the **N** thus obtained is not pure. Remove receiver, and over a pneumatic tub fill a smaller jar with the gas. Remove small jar, and test by passing a lighted taper up into the gas. The flame is extinguished and the **N** does not take fire.

Nitrogen is a colorless gas, without odor or taste. It forms by volume $\frac{4}{5}$ **of the atmosphere.** N is not poisonous, and destroys life only by shutting out O. It is **not inflammable** and it does **not support combustion.** It is a very **inert** element. It dilutes the active O of the air, and the mechanical mixture is thus fitted for respiration. Some of its *compounds* are by no means inert. For example, **"nitro-glycerine"** the violent explosive is **glyceryl nitrate,** and the deadly poison, prussic acid, is hydrogen cyanide. No one can predict with certainty the character of a chemical compound from the nature of its constituents. It might be supposed that, N being lighter than O, the air would separate into two layers, the heavier, O, sinking. The two gases, however, are kept thoroughly mixed by the law of **diffusion of gases.**

N forms with **O** five oxides, viz.:—

$\mathbf{N_2O}$, hyponitrous oxide (acid-forming).
$\mathbf{N_2O_2}$ nitrogen dioxide.
$\mathbf{N_2O_3}$ nitrous oxide (acid-forming).
$\mathbf{N_2O_4}$ nitrogen tetroxide (or peroxide).
$\mathbf{N_2O_5}$ nitric oxide (acid-forming).

These oxides illustrate well the great law of **multiple proportions.** When one substance unites *chemically* with another, it is in some definite proportion, *or* **multiple of that proportion.** Whenever substances are united *physically* (mechanically, as in alloys of metals, etc.) they may be united (mixed) in any proportion.

NOTE.—We see from the above that there is a third class of **indifferent oxides** (as N_2O_2, N_2O_4), neither acid-forming nor basic. The pupil need not give much attention, however, to this class. All the positive indifferent oxides, as MnO_2, BaO_2, K_2O_4, PbO_2, having more O than the basic, are called **peroxides.** For preparation of N_2O_3 and N_2O_5 see larger text books.

EXP. 36.—Heat in flask ammonium nitrate and collect gas over pneumatic tub of *warm* water.

$$\overline{H_4N}\,\overline{NO_3} = 2H_2O + N_2O\uparrow$$

Hyponitrous oxide (**"nitrous oxide"** "laughing gas,") inhaled with a small proportion of O, produces a peculiar intoxication, hence its name of "laughing gas." If the pure gas is inhaled, it soon produces insensibility. It is much used as an **anæsthetic** by dentists and by surgeons in minor operations. It is kept condensed in liquid state in iron cylinders.

EXP. 37.—To small pieces of copper add dilute (25 per cent.) nitric acid, red fumes appear in generator (see EXP. 38), but a colorless gas collects over the tub.

Reaction (irregular): $Cu_3 + 8H\overline{NO_3} = 3Cu2\overline{NO_3} + 4H_2O + N_2O_2\uparrow$

[Filter water in flask, evaporate, and obtain blue crystals of $Cu2\overline{NO_3}$].

EXP. 38.—Admit to test tube containing N_2O_2 a bubble (air). Red fumes of N_2O_4 appear.

$$N_2O_2 + O_2 = N_2O_4\downarrow$$

These fumes are soluble in water, and the [illegible] the place of the dissolved gas.

Exp. 39.—Into a small retort put 4 gms. of sodium nitrate (or $K\overline{NO_3}$) and 2 gms. of sulphuric acid (previously diluted to 90 per cent.) Carefully heat. Collect nitric acid (impure and slightly diluted) in well cooled test tube, as in Fig. 18.

$$2Na\overline{NO_3} + H_2\overline{SO_4} = Na_2\overline{SO_4} + 2H\overline{NO_3}$$

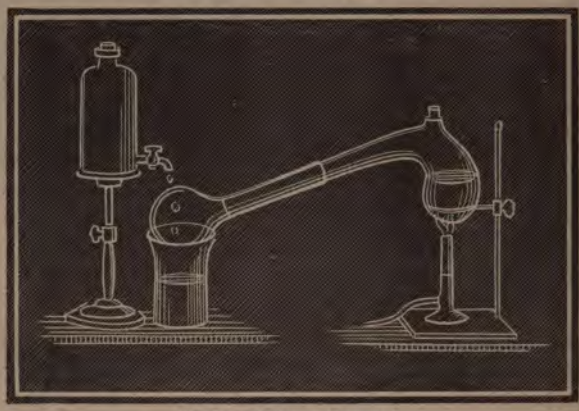


Fig. 18.—Making nitric acid.

Exp. 40.—Boil quill in $H\overline{NO_3}$. It turns yellow.

Exp. 41.—To dilute $H\overline{NO_3}$ add a crystal of $Fe\overline{SO_4}$; then add a few drops of $H_2\overline{SO_4}$. A brown compound ($FeSO_4, N_2O_2$) forms about the crystal. This is a good test for $H\overline{NO_3}$.

Exp. 42.—Throw a crystal of a nitrate upon a red-hot coal. The coal burns rapidly (almost explosively).

Nitric acid (old name **aqua fortis**) is a colorless (if pure), fuming, corrosive liquid. It stains organic matter, as the skin, nails, etc., a **dingy yellow.** It is a powerful **oxidizing agent,** as are all the other nitrates.

Exp. 43.—Spread upon a piece of copper and also upon a piece of iron a thin layer of paraffine. Write a word upon each with a needle. Upon the writing put nitric acid (50 per cent.) It etches the words by oxidizing the metals, dissolving and uniting with the metallic oxides.

Nitric acid is used in **etching** upon copper and iron (copperplate, swords, razors).

Exp. 44.—Into a test tube containing nitric acid, drop a piece of gold leaf and heat. It does not dissolve. Add a few drops of hydrochloric acid. The gold rapidly dissolves, forming $Au Cl_3$ in solution.

Nitric acid (about 3 parts) and **hydrochloric acid** (5 parts) form **aqua regia,** the solvent of gold (and platinum).

Exp. 45.—Place in a flask a little ammonium chloride (sal ammoniac) with an equal weight of calcium oxide (quicklime), each finely pulverized. Add a few drops of water and heat. Dry gas by passing through bottle containing **Ca O**. Collect by displacement of air, as in Fig. 19.

$$2\,H_4N\,Cl + Ca\,O = Ca\,Cl_2 + H_2O + 2\,H_3N$$

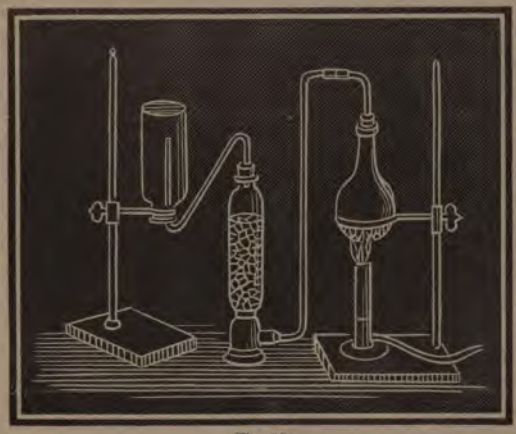


Fig. 19.

Exp. 46 (45 concluded).—Quickly close mouth of bottle of ammonia by perforated rubber cork, through which passes a glass tube drawn to a fine point. Connect with water colored *red* by (acidulated) litmus and hasten the action by forcing air into lower flask (at A, Fig. 20) few drops of water reach the receiver of ammonia. The gas so rapidly in the water, that a partial vacuum is form

side atmospheric pressure produces the "ammonia fountain." The water turns blue as it enters the receiver.

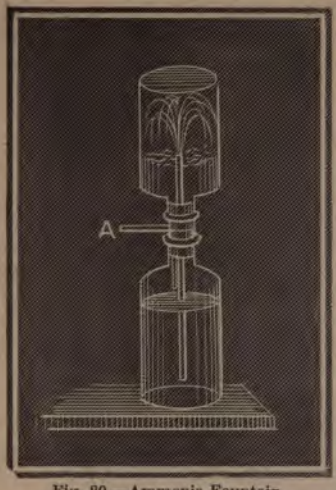


Fig. 20.—Ammonia Fountain.

Ammonia is a colorless gas, with *pungent* odor. It is much *lighter* than air. It is **very soluble** in water, 700 gals. dissolving in a single gallon of water at 15° (1000 + vols. at 0°). It not only dissolves, but unites ($H_3N + H_2O = \overline{H_4N}\,\overline{HO}$) forming ammonium hydrate ("ammonia water," hartshorn, etc.) The ammonium grouping can be passed from compound to compound like an element, and hence is a compound radical. (See AMMONIUM). Ammonia in the presence of moisture ($\overline{H_4N}\ \overline{HO}$) has a strong alkaline reaction, but its effect upon vegetable colors is only temporary, and it has been called the "volatile alkali." In concentrated "ammonia water" there is a large excess of the gas dissolved (more than unites with the water).

"Evaporation cools." This means, that when a substance evaporates, it absorbs heat from what is near by. (See SULPHUR DIOXIDE). Wet one hand and pass both hands rapidly through the air. The wet hand is sensibly colder from the evaporation of the water. Pour a little ether upon the thermometer bulb. The ether quickly evaporates and the mercury falls.

A pressure of about 4½ atmospheres (at 0°) converts gaseous into liquid ammonia. The evaporation of liquid ammonia produces intense cold (—40°). Advantage is taken in the arts of this fact to produce **ice** artificially.

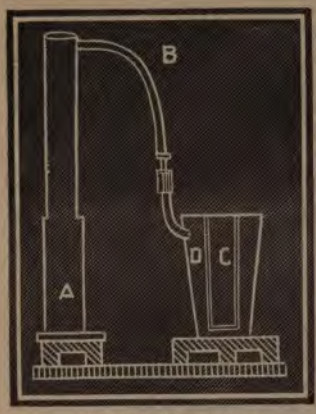


Fig. 21.—Ice machine.

In a strong generator A is placed ice water saturated with ammonia gas (1,000 vols. in one). This is connected with an equally strong receiver D by the tube B. Receiver D is placed in cold water. Heat is applied to A and the great pressure of the escaping gas converts itself into a liquid in D. Water is now placed in vessel C. Generator A is cooled and the liquid ammonia in D evaporates and is reabsorbed by water in A. The evaporation produces sufficient cold (takes away or absorbs sufficient heat) *to freeze water in* C.

Nitrogen and hydrogen do not unite directly to form ammonia, but when decomposition is taking place in organic substances and these two elements are leaving their old compounds, they unite. Elements just leaving their old compounds are said to be in the **nascent** state, and they have a much greater tendency to form new compounds.

CHAPTER XXI.

CARBON.

Carbon is a very abundant element. It forms a large proportion of vegetable and animal tissues and is a prominent constituent of limestone, marble, etc. (**carbonates**). We know it in three allotropic states:—

1. **Diamond.**
2. **Graphite** (plumbago, black lead).
3. **Amorphous carbon** (uncrystallized).

Graphite, mixed with a little Sb and S is used to make common "lead pencils." Mixed with clay, it makes crucibles, the most *refractory* (difficult to melt, or of ores, difficult to reduce) known.

Amorphous carbon (more or less impure) includes charcoal, mineral coal (the remains of vegetation of the carboniferous age), coke, peat, animal charcoal (bone black), soot, lamp black, and gas-carbon.

NOTE.—For fuller description of the above and of all such substances briefly mentioned in this primary work, see the dictionary and cyclopædia. Every High School should have an unabridged dictionary and a cyclopædia *placed where scholars can readily refer to them.*

Carbon for a long time resists decay. Fence posts are charred to preserve them. Neither acids (except nitric) nor alkalies affect it.

EXP. 47.—Collect in test tube over mercury (or by displacement of air) H_3N. Introduce into the gas a piece of fresh burnt, dry charcoal, mounted on wire attached to perforated cork, and quickly dip the mouth of test tube beneath mercury. The **Hg** rises in test tube, because **C** absorbs the H_3N in its pores.

Carbon absorbs many times its bulk of gases, condensing them in its pores. Fresh burned charcoal is a good **"disinfectant"** for foul gases. They are destroyed within its pores by the absorbed O; *i. e.*, by oxidation, (so that C is not a disinfectant in a strict *chemical* sense, but its action is mechanical). O is the real disinfectant.

EXP. 48.—Place *finely* pulverized charcoal upon filter. Moisten with distilled water. Let ink (or indigo solution, vinegar, etc.) fall drop by drop upon the charcoal from an ordinary filter paper above it. The filtrate from charcoal is colorless.

Charcoal is a good **decolorizing agent.** Animal charcoal is largely used in sugar refineries to remove soluble impurities and color.

EXP. 49.—Heat upon platinum foil a piece of sugar (or organic matter, as tartaric acid, flesh or vegetable). It chars (turns black, as the more volatile constituents are driven off, leaving the carbon free).

Charring is a good test for carbon (or for organic matter).

EXP. 50.—Upon charcoal put a little litharge (**Pb O**). Heat in the blow-pipe flame. The **O** is taken by the **C**, leaving the **Pb** *free* (uncombined).

$$2\,PbO + C = \underset{\text{metallic lead}}{Pb_2} + CO_2\uparrow$$

Carbon is a good **deoxidizing** (chemical term) or **reducing** (mining term) **agent.** Heated with the oxides of most metals it deoxidizes them, and is thus of special use in reducing ores that are oxides (or carbonates, since great heat breaks up the carbonate grouping, setting CO_2 free, and leaving an oxide behind).

EXP. 51.—Upon pieces of marble **Ca $\overline{CO_3}$** in a flask, pour dilute (20 per cent.) **H Cl.** Collect gas by displacement of air.

Reaction (class 4): $\underset{\text{carbonate}}{Ca\,\overline{CO_3}} + \underset{\text{acid}}{2\,HCl} = \underset{\text{salt}}{CaCl_2} + \underset{\text{water}}{H_2O} + \underset{\text{carbonic oxide.}}{CO_2\uparrow}$

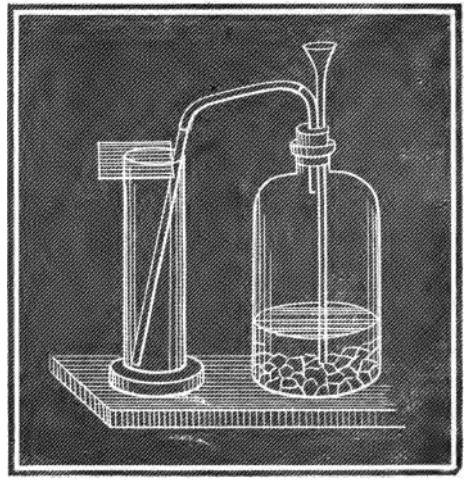


FIG. 22.

Carbonic oxide (carbon dioxide, carbonic anhydride, old name **carbonic acid**) is a colorless gas, with slightly acid taste. It is much **heavier** than the air (sp. gr. 1.5) in which it exists free, forming $\frac{4}{10000}$ by volume.

EXP. 52.—Into a jar of CO_2 introduce a lighted taper. It is extinguished.

EXP. 53.—Arrange lighted candles along an inclined trough (piece of gutter). Pour a large receiver of CO_2 down the trough. The candles go out in order as CO_2 reaches them.

EXP. 54.—Put a mouse into a receiver of CO_2. The animal dies.

Carbonic oxide does **not support combustion** and **is not inflammable.** It is not poisonous, but animals die in it from want of free O, that is from suffocation or asphyxia.

EXP. 55.—Burn **Mg** ribbon in a jar of CO_2. Black particles of carbon appear mixed with the white oxide.

$$CO_2 + Mg_2 = \underset{\text{white}}{2MgO} + \underset{\text{black}}{C}$$

Dissolve oxide in dilute $H\overline{NO_3}$ and **C** is made more distinct. CO_2 supports the combustion of magnesium.

EXP. 56.—Into a jar of CO_2 that has been tested by taper, pour lime water ($Ca2\overline{HO}$), the water becomes milky. (Or the gas may be passed into lime-water).

Reaction (class 3): $\underset{\text{base}}{Ca2\overline{HO}} + \underset{\text{acid-forming oxide}}{CO_2} = \underset{\substack{\text{salt}\\ \text{(white precipitate)}}}{Ca\overline{CO_3}} + \underset{\text{water}}{H_2O}$

Lime-water is the test for CO_2. No other gas will (1) extinguish flame and (2) render lime-water milky.

EXP. 57.—Hold the breath a short time and then expel the air into a receiver. Test. It extinguishes the flame of taper and turns lime-water milky.

Fig. 23.

Animals exhale CO_2 from the lungs as a waste product. They use up O from the air and replace it by CO_2.

Exp. 58.—Place a small branch with leaves in a tall receiver of water, previously boiled to expel gases, and expose for a few hours to direct sunshine. **O** is evolved and collects in the top of receiver. Test by glowing taper.

Plants in sunshine exhale through their leaves O (except certain low orders), using up CO_2 of the air and building the C into their tissues. The leaves of plants correspond to the lungs of animals. They receive the air through little stomata (mouths) on the under side (principally). The plant, however, does much more through its leaves than merely to respire. It gets vastly more food (by weight) from the air than from the richest soil.

Plants thus purify the air for animals, and the proportion of CO_2 remains the same, notwithstanding the enormous yearly combustion of coal. Animals by a reverse process supply from their own waste the needed elements of plant food.

CO_2 tends to collect in old wells and in unventilated portions of mines. It is called by miners **choke-damp.** Wherever a light is extinguished by **CO_2**, it is unsafe to go.

Exp. 59.—Place a short lighted candle on a rubber cork and introduce it into the bottom of a vertical glass tube, which the cork fits. The candle goes out. In the tube suspend a smaller tube and introduce the lighted candle as before. It burns steadily. The heated air (and **CO_2**) rises in the small tube (upward draft) and the fresh air containing **O** falls between it and the larger tube.

Two openings, at least, are necessary for proper ventilation. In mines, where it is possible, two shafts, one at each end, with a fire at

the base of either, answers the purpose. Very complex arrangements, however, have to be made in many cases to force air into the various parts of large mines. Plenty of fresh air is the only preventive to keep fire-damp (marsh gas CH_4) and CO_2 from accumulating in dangerous quantities.

EXP. 60.—Hold the breath a short time and then expel it into a jar and close by rubber cork. Set aside in a warm place for a day or two and then open. A very offensive putrescent odor greets the sweetest-breathed experimenter. (CO_2 has no odor).

Churches, school-rooms, bed-rooms, etc., should be very thoroughly ventilated, not so much to free them from the injurious CO_2 as to remove the **poisonous "animal vapor"** (moisture in suspension) thrown off from the lungs. This "vapor" holds all manner of organic impurities in solution.

EXP. 61.—Fill a small bottle with CO_2. Close with the thumb and open under water, pressing the mouth a few inches below the surface. Close the bottle, remove and shake. Part of the CO_2 dissolves. Open under water and repeat shaking. In this way the bottle of CO_2 may be dissolved in a bottle of water.

Water at 15° dissolves one vol. of CO_2, but if the gas is under pressure, it dissolves much more.

"Soda Water" is nothing but a solution of CO_2 under pressure in water. It probably receives its inappropriate name because of its effervescence when relieved of pressure (like sodium carbonate, "soda," when mixed with an acid).

CO_2 has been condensed to a liquid, and by rapid evaporation of a part, the rest is solidified (frozen), forming a snow-white solid. This solid is so cold, that when touched it produces the same effect as red-hot iron (see similar condensation of SO_2).

Fig. 24.

As we have seen, CO_2 and H_2O are the two great products of ordinary combustion. The chemistry of a burning candle is in a general sense very simple. The wick is first raised to the igniting point and the heat melts the tallow (composed chiefly of H and C combined) and the liquid is then drawn up by capillary attraction into the wick. Here the great heat changes the liquid tallow into the gaseous state (with decomposition into various hydrocarbons). *Flame is burning gas.* The flame is hollow, as no O can penetrate to its center, and the hollow is filled with the unburnt gases. (These may be drawn away by a fine glass tube and burned at its end, if the candle is a large one). In floating outward the C from the decomposed hydrocarbons becomes white hot and gives out light, but soon meets the O of the air and becomes CO_2 at the instant it ceases to give light. Outside is a faintly blue cone cup-shaped at the bottom and composed of burning H (and CO). If a cold piece of glass or porcelain is introduced into the flame the C is lowered below the igniting point and is deposited as smut. The H_2O (steam) is condensed and deposited also.

Illuminating gas is made from bituminous coal by heating in retorts and collecting volatile hydrocarbons in a holder. It contains various gases, **H, CO, CH_4** (**marsh gas**, "fire damp" of mir **C_2H_4** (**olefiant gas**, ethylene), **C_6H_6** (vapor of benzol), e (before purification) others that must be removed, as **H_2N** (and other sulphur compounds), besides vapor of "tar."

complex substance, from which the aniline dyes, carbolic acid, etc., are obtained. H_3N may be removed by passing through water (or **H Cl**, old method), CO_2 by passing through "pans" of lime (**Ca O**), and the sulphur compounds by passing over ferric hydrate. The last reaction may be represented thus:—

$$\underset{\text{ferric hydrate}}{Fe_2 6HO} + \underset{\text{hydrogen sulphide}}{H_2S} = \underset{\text{ferrous hydrate}}{2Fe\,2HO} + \underset{\text{water}}{2H_2O} + \underset{\text{free sulphur}}{S}$$

Fig. 25.—Section of Gas Meter. The three arrows represent the rotation of the chambers: the solitary arrow the escape of the gas from chamber. Gas enters through the U-shaped center.

On exposure to the air, ferrous hydrate becomes ferric hydrate, and the material may be repeatedly used till the free sulphur forms from 40 to 50 per cent. The tar vapor condenses and runs into the "tar well." The refuse (coke) is left behind in the retorts.

The purified gas is measured by the meter and passes into the holder, from which it is distributed to consumers. Illuminating gas is also made from crude petroleum, more complex machinery being used.

Bunsen's Burner is represented in Fig. 9 and is used when *heat*, not light, is wanted. The gas is mixed with the air, drawn in through openings at the side. The flame is condensed, is much hotter, and does not smut cold glass.

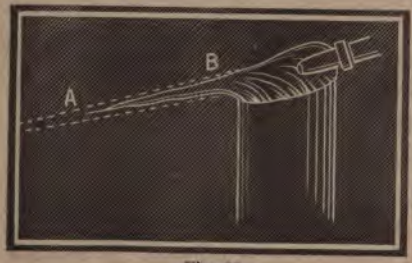


Fig. 26.

Exp. 62.—Heat in extreme tip of blowpipe flame the end of a copper wire. It turns black, *i. e.*, is oxidized, forming **Cu O.** Heat in the midst of flame nearer the blowpipe. The **Cu O** is reduced (deoxidized) and the bright metallic copper appears.

By means of the **blowpipe** we may do *two* things, **oxidize** most metals (a very small portion is sufficient for tests) and **reduce** their oxides.

At A a substance may be oxidized because here we have an excess of **O** thrown forward from the blowpipe and highly heated. The flame at B is reducing, for here there is an excess of highly heated carbon. The reducing flame is best produced by holding the nozzle of blowpipe a very short distance from the flame instead of in it. The **blowpipe** is a very valuable instrument in the **analysis of ores.**

Exp. 63.—Two inches above a gas burner hold a fine wire gauze and ignite jet of gas above the gauze. It burns above, but not below. The wire being a good conductor of heat reduces the gas below the igniting point, and the flame cannot pass through the gauze.

Fig. 27.—Wash Bottle.

Davy's Safety Lamp used by miners is essentially a lamp surrounded by a wire gauze. The flame cannot pass through this to ignite the "fire damp" (CH_4 marsh gas). This dangerous gas explodes violently when mixed with air and ignited.

Exp. 64.—Into a flask put a small quantity of oxalic acid crystals and cover with strong sulphuric acid. Heat gently and pass gases through wash bottle containing strong solution of $\overline{KHO}$. Collect over water.

$$H_2\overline{C_2O_4} = H_2O + CO_2' + CO'$$

The sulphuric acid absorbs H_2O from the oxalic acid breaking up the molecule. The $\overline{KHO}$ solution absorbs the CO_2 becoming $K_2\overline{CO_3}$ (and H_2O) and the CO is collected in receiver. Test by lighted taper. It burns with bluish flame.

Carbonous oxide C O, (old name carbonic oxide) is a colorless **poisonous** gas formed by burning C in a close atmosphere. Escaping from hot stoves through the pores of the iron into ill-ventilated rooms, it causes headache. In large quantities it speedily produces coma and de
pale, lambent flame that plays over a b
coals after the brighter flame is spent, is
gas.

NOTE.—**Organic chemistry** may be considered as *carbon continued.* The previous rules for writing formulas and names, which hold so generally in inorganic chemistry, fail in numberless instances to meet the requirements of organic chemistry, as we shall see (see ORGANIC CHEMISTRY).

CHAPTER XXII.

BINARY ACID- AND SALT-FORMERS.

FLUORINE, CHLORINE, BROMINE, IODINE, AND CYANOGEN.

EXP. 65.—Into a small flask on a sand bath, put equal weights of common salt and manganese dioxide, well mixed. Add sufficient water to make thin paste. Pour in through funnel a small quantity of sulphuric acid (90 per cent.) and collect gas in large test tube over hot water, or by displacement of air in *deep* receivers. Heat should be applied to flask to drive off the last (and greater portion) of the gas. A double reaction takes place:—

(1)—$H_2\overline{SO_4} + 2NaCl = Na_2\overline{SO_4} + 2HCl\uparrow$

(2)—$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2\uparrow$

The gas may be freed from **H Cl** by passing through wash bottle (see Fig. 27) of cold water. It may be dried, if desired, by passing through strong H_2SO_4 in the same manner, and then collected by displacement of air.

Caution.—Care should be taken not to breathe (except in minute quantities) chlorine, cyanogen, or, in short, any gases or products that are poisonous. Small quantities of such gases should be used in experiments. If larger quantities are desired, they should be made under a "gas chimney," or near a window with outward draft.

Chlorine is a *greenish-yellow, poisonous* gas of a suffocating odor. When very dilute it produces coughing (relieved by cautiously inhaling ammonia), and breathed in larger quantities inflammation of the trachea and bronchial tubes. It is **2.5** times heavier than air. It is an abundant element, but is not found free in nature.

Fig. 28.

Exp. 66.—Into a jar of **Cl** plunge a lighted pitch-wood taper. It burns awhile with smoky flame. The **Cl** unites with **H** of the taper, setting the **C** free as smoke. Test by blue litmus.

Exp. 67.—Burn a jet of **H** in **Cl** and test product by blue litmus.

$$\mathbf{H} + \mathbf{Cl} = \mathbf{H\acute{C}l}$$

Exp. 68.—Into a jar of **Cl** introduce a piece of blotting paper moistened with *fresh* and *warm* turpentine ($\mathbf{C_{10}\ H_{16}}$). The **Cl** unites with the **H** so vigorously as to cause it to take fire, but the **C** is set free as a dense cloud of smoke.

$$\mathbf{C_{10}H_{16}} + \mathbf{Cl_{16}} = \mathbf{16\,H\acute{C}l} + \mathbf{C_{10}}$$

Test by litmus.

Cl has a great affinity for H. Upon this affinity depends its value as a **disinfectant.** H is an essential constituent of many foul gases. Cl destroys them as it destroys coloring matters. (See Exp. 72).

Exp. 69.—Upon paper containing printer's ink write with common ink (iron tannate $\mathbf{Fe_2(C_{27}H_{19}O_{17})_3}$) and lower into [illegible] of **Cl**. The common ink is bleached, but the printer's ink [illegible] black, **C**) is unaffected.

Exp. 70.—Into a black bottle [illegible] (purified of **H Cl**). The **Cl** dissolves in water." Set aside as a reagent.

ing agents. Potassium chlorate is one of the most important of the chlorates.

Exp. 81.—In a deep test tube thoroughly mix a little pulverized **K Br** and **Mn O_2**, adding **$H_2\overline{SO_4}$** (90 per cent.) and gently heating. The reddish and irritating fumes of bromine appear. These may be condensed into a liquid in deep test tube cooled in ice water.

(1)—**$H_2\overline{SO_4}$ + 2 K Br = $K_2\overline{SO_4}$ + 2 H Br**

(2)—**MnO_2 + 4 H Br = $MnBr_2$ + 2 H_2O + Br_2**

Bromine is a *volatile, poisonous,* dark red **liquid,** very similar in its properties to chlorine, but less active. Many experiments analogous to those under Cl may be performed with bromine vapor. Thus, Br **bleaches** and unites with H to form hydrobromic acid. H Br and other soluble bromides precipitate silver as *yellow* silver bromide, which blackens in sunlight like silver chloride. (Perform experiments and write reactions). Br is not a very abundant element.

Exp. 82.—Boil a very small piece of starch (**$C_6H_{10}O_5$**) in water, and add a drop of the starch solution to bromine water. A *yellow* solution of bromide of starch appears.

Starch solution is a very good test for free bromine (see Exp. 85).

Exp. 83.—Repeat Exp. 81, substituting **K I** for **K Br**, *violet colored vapor* of iodine appears and condenses as a *solid* on sides of test tube.

Iodine is a greyish-black *solid* with metallic lustre. It is a comparatively rare element.

Exp. 84.—To tincture *(solution in alcohol)* of iodine very dilute, add dilute solution of starch paste. *Blue* iodide of starch appears. [That the compound is not a very stable one, may be shown by gently heating. The blue color disappears (if solution was dilute), but reappears as the solution cools].

Starch is a very delicate **test** for *free* iodine (See Exp. 85). Soluble iodides precipitate silver as silver iodide which blackens in sunlight.

Exp. 85.—Into a test tube put solution of **K Br**, and into test tube **K I**. Add to each two or three drops of starch.

No *yellow* or *blue* color appears, because the **Br** and **I** are combined with **K**. To each add one drop of chlorine water. The *yellow* and the *blue* colors appear because the **Cl** unites with the **K** setting the **Br** and **I** free.

(1)—$KBr + Cl = KCl + Br$ (free).

(2)—$KI + Cl = KCl + I$ (free).

The free **Br** and **I** then unite with the starch forming the *yellow* and the *blue* color respectively.

This experiment shows the superior **chemism (chemical affinity)** or activity of chlorine.

Fluorine is the only element which does not unite chemically with oxygen. It is supposed to be a colorless gas, but so great is its **chemical affinity** that it has not been satisfactorily isolated (set free).

Exp. 86.—In a platinum or lead crucible place two grams of Fluor Spar (CaF_2) and cover with strong $H_2\overline{SO_4}$. Coat a piece of glass at a gentle heat with beeswax, and having written with a zinc point (which will not scratch the glass) a word upon the wax, gently heat crucible, and removing lamp, cover with glass. Leave over night. The word is etched upon the glass.

(1)—$CaF_2 + H_2\overline{SO_4} = Ca\overline{SO_4} + 2HF\uparrow$

(2)—$4HF + \underset{\text{of the glass } (Na_4\ \overline{SiO_4})}{SiO_2} = 2H_2O + SiF_4\uparrow$

Hydrofluoric acid (H F) is used for **etching** letters or beautiful designs upon glass. If the gas is used the letters or designs are left rough; but if a solution of the gas in water (kept in *gutta percha bottles*) is used, the etched portion is smooth.

Exp. 87.—In a tube of hard glass place a small quantity of mercuric cyanide ($Hg\,2\,\overline{CN}$). Heat carefully to dull redness and collect gas in test tube over mercury. Test by lighted taper. The gas burns with reddish-purple flame.

(1)—$Hg\,2\,\overline{CN} = Hg + (\overline{CN})_2\uparrow$

$\overline{CN} + O_2 = CO_2\uparrow + N\uparrow$

Cyanogen ($\overline{CN}$ or Cy) is a colorless, pungent, inflammable gas with strong *peach-blossom* odor. As the molecule of hydrogen has been represented thus $\boxed{H\ H}$, so the molecule of free cyanogen may be represented thus $\boxed{\overline{CN}\ \overline{CN}}$ or $\overline{C_2N_2}$.

It is interesting as being the first "**compound radical**" isolated. It forms binary salts, several of which are very important. The intensely poisonous prussic acid (hydrogen cyanide, $H\overline{CN}$) may be formed by the action of sulphuric acid on potassium cyanide. *(Do not perform the experiment).*

$$2K\overline{CN} + H_2\overline{SO_4} = K_2\overline{SO_4} + 2H\overline{CN}$$

CHAPTER XXIII.

NORMAL SALTS, ACID SALTS, ETC.

A **normal salt** (old name neutral salt) is one which is formed by replacing all the replaceable hydrogen of the acid by a positive element or grouping.

EXAMPLE.

$H_2\overline{C_4H_4O_6}$ = hydrogen tartrate = acid.

$K_2\overline{C_4H_4O_6}$ = potassium tartrate = normal salt.

NOTE.—Hitherto by salts have been meant normal salts.

An **acid salt** is one which is formed by replacing only part of the replaceable hydrogen of the acid by a positive element or grouping.

EXAMPLE.

$H_2\overline{C_4H_4O_6}$ = hydrogen tartrate = acid.

$HK\overline{C_4H_4O_6}$ = { hydrogen potassium tartrate or acid potassium tartrate } = acid salt.

Acid salts usually turn blue litmus red, but this is by no means universal. In EXP. 39, if one-half as much sodium nitrate be taken, with strong sulphuric acid, an acid salt, instead of a normal salt results.

$$Na\overline{NO_3} + H_2\overline{SO_4} = \underset{\text{acid sodium sulphate}}{HNa\overline{SO_4}} + H\overline{NO_3}$$

In general, by adding an excess of the acid (which is the same as taking less of the other substance), an acid salt may be obtained. Acid salts, as a rule, react with carbonates like acids, that is, forming a *salt*, (normal), *water* and *carbonic oxide*, as:—

$$\underset{\text{acid salt}}{2HK\overline{C_4H_4O_6}} + \underset{\text{carbonate}}{K_2CO_3} = \underset{\text{normal salt}}{2K_2\overline{C_4H_4O_6}} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2}$$

A **double salt** is one which is formed by replacing part, or all of the replaceable hydrogen of the acid by two positive elements or groupings.

EXAMPLE.

$H_2\overline{C_4H_4O_6}$ = tartaric acid.

$KNa\overline{C_4H_4O_6}$ = potassium sodium tartrate = double salt.
("Rochelle salt")

$H_3\overline{PO_4}$ = phosphoric acid.

$HNaH_4\overline{NPO_4}$ = hydrogen sodium ammonium phosphate = double salt (microcosmic salt). A double salt may be at the same time an acid salt, like the last.

A double salt may be formed by an acid salt of one metal acting on the carbonate of the other, thus:—

$$\underset{\text{sodium carbonate}}{Na_2\overline{CO_3}} + \underset{\text{acid potassium tartrate}}{2HK\overline{C_4H_4O_6}} = \underset{\text{double salt}}{2KNa\overline{C_4H_4O_6}} + \underset{\text{water}}{H_2O} + \underset{\text{carbonic oxide}}{CO_2}$$

Acids containing one, two, three, etc., atoms of replaceable hydrogen are said to be respectively **monobasic, dibasic, tribasic,** etc.

EXAMPLES.

$H\overline{NO_3}$ = mono-basic acid.
$H_2\overline{SO_4}$ = dibasic acid.
$H_3\overline{PO_4}$ = tribasic acid.
$H_4\overline{SiO_4}$ = tetrabasic acid.

NOTE.—A tribasic acid may form *two* acid salts, as:—

$H_2Na\overline{PO_4}$ = dihydrogen sodium phosphate = acid salt.
$HNa_2\overline{PO_4}$ = hydrogen disodium phosphate = acid salt.

A **basic salt** is one which may be formed by replacing one or more hydrate groupings of the base by a negative grouping. (This definition is a narrow one, covering most but not all basic salts).

EXAMPLE.

$Pb\,2\overline{HO}$ = lead hydrate = base.
$Pb\overline{HO}\,\overline{NO_3}$ = lead hydro-nitrate = basic salt.
$Al_2\,6\overline{HO}$ = alumnium hydrate = base.
$Al_2\,2\overline{HO}\,\overline{SiO_4}$ = alumnium hydro-silicate = basic salt.

Sulph- and **Selen-acids** and **salts.** In all formulas for ternaries thus far used, oxygen has been the last element. It is supposed to be principally a *linking* or *connecting* element. Now there are a few other dyad elements that can perform this office of linking, especially **sulphur** and **selenium.** To write the formula for a sulph- or a selen-acid or salt, the same reference table may be used, only sulphur or selenium, as the case may be, must be substituted *atom for atom,* in place of oxygen.

EXAMPLE.

$K\overline{CO_3}$ = potassium carbonate = salt.
$K_2\overline{CS_3}$ = potassium sulpho-carbonate = sulph-salt.
$Ag_3\overline{AsO_4}$ = silver arsenate = salt.
$Ag_3\overline{AsS_4}$ = silver sulph-arsenate = sulph-salt.
$K_3\overline{SbO_3}$ = potassium antimonite = salt.
$K_3\overline{SbSe_3}$ = potassium selen-antimonite

$H_3\overline{AsS_4}$ = hydrogen sulph-arsenate = sulph-acid.

NOTE.—Instead of sulph-, thio- (Greek *thion*, sulphur) is used by some chemists, as $K_2\overline{CS_3}$ = potassium thio-carbonate.

The sulph- and selen-acids and salts are few compared to those containing oxygen.

MISCELLANEOUS QUESTIONS.

1. Reaction in making **O**?
2. How many litres of **O** can be made from 150 grams of $K\overline{ClO_3}$? (NOTE.—**A litre of H weighs .0896 grams** (at 0° and barometer 760 mm), and a litre of **O** weighs 16 times as much, a litre of **N** 14 times as much, etc., according to the *atomic weight of the gas*. To find the weight of compound gases, *multiply the weight of* **H** *by one-half the molecular weight of the gas*. Ex.—A litre of CO_2 weighs 22 times .0896 gms.).
3. Tell what you know about **O** (ten lines).
4. Give experiments proving the character (properties) of **O**
5. Reaction in making **H**?
6. How many litres of **H** could be made by using 5 grams of **Zn**?
7. How many grams of **Zn** must be used to make 15 litres of **H**?
8. Give properties of **H** and prove by detailing experiments.
9. What is a deliquescent salt? An efflorescent salt?
10. How was **N** obtained?
11. Give the composition of air.
12. What was proved by the "ammonia fountain"?
13. What is "aqua regia"? and why so called?
14. What is meant by "nascent" hydrogen?
15. Give EXP. proving that **C** is a good decolorizing agent.
16. Give EXP. showing that *fresh burned* **C** is good "disinfectant."
17. How may CO_2 be made?
18. Fifty litres of CO_2 could be made by using what quantity (grams) of $Mg\overline{CO_3}$?
19. Detail three experiments under carbonic oxide.
20. Animals and the higher orders of plants differ with respect to use of CO_2 and **O**. How?
21. Write 5 lines about chlorine, saying the most possible.
22. How is glass etched? Copper and iron?

[illegible] is cyanogen? [illegible] it treated in the chapter on [illegible] amine, etc., rather [illegible] or nitrogen or carbon?

[illegible] ts, two basic salts and one [illegible] e sulph-acid and two selen-

CHAPTER XXIV.

SULPHUR AND PHOSPHORUS.

Sulphur is found free (native) *in volcanic regions.* It is found combined in cinnabar, (Hg S) iron pyrites (FeS_2), galena (Pb S), blende (Zn S) etc. It is contained in most animal tissues and especially in the perspiration and hair, also in many vegetables, especially in those that are strong-smelling.

EXP. 88.—Drop a bright silver coin upon white of egg and leave over night. It is blackened.

Eggs contain sulphur and so tarnish silver spoons, *black* silver sulphide (Ag_2S) being formed.

EXP. 89.—Into a dilute solution of lead acetate introduce white horse-hairs (also into silver nitrate solution). Leave over night. They are colored black.

Many "hair dyes" contain salts of lead or silver. The metal unites with **S** of the hair, forming *black* **PbS**, or *black* Ag_2S. Such hair dyes are highly injurious.

Sulphur exists in several allotropic states, among which are (1) the crystallized, (2) the common uncrystallized ("amorphous"), and (3) the plastic (viscid, also uncrystallized).

EXP. 90.—Melt **S** and let cool. *Crystals* form at the bottom of the liquid. Dissolve brimstone in carbon disulphide (CS_2), allow to evaporate over night. Crystals of **S** are left (see chap. xxiii).

EXP. 91.—Heat sulphur for about five minutes, or till melted mass at first thick becomes thin. Quickly pour into cold water. Plastic **S** results. This form is unstable and becomes brittle in a few days.

EXP. 92.—In a small tube of hard glass closed at one end heat iron pyrites (FeS_2). Part of the sulphur sublimes and condenses on cold part of the tube.

$$3\,FeS_2 = Fe_3S_4 + S_2$$

NOTE.—A substance *sublimes* when it rises as a vapor and condenses as a solid. A substance *distills* when it rises as a vapor and condenses as a liquid.

S is obtained from Iron pyrites by "roasting" the ore and condensing the **S**.

EXP. 93.—Repeat EXP. 3, placing in the bottle a red rose. The rose is bleached. Immerse in dilute sulphuric acid, the color is restored.

Sulphur dioxide is used in **bleaching** *silk*, *straw* and *woolen* goods which would be injured (turned yellow) by chlorine. Colorless compounds are formed by the union of the SO_2 with the coloring matter, but the reaction is complex.

SO_2 is also an **antiseptic.** S burned in a vessel prevents the fermentation of the liquid (as new cider) afterwards put in. Like all strong antiseptics it is poisonous.

EXP. 94.—Place in a small flask (*provided with safety tube* as in FIG. 22, or as in H_2S generator in FRONTISPIECE 2) pieces of copper foil (or wire) and add as much strong H_2SO_4 as will not quite cover the copper. Carefully heat until gas begins to be evolved and then remove heat; else the liquid froths from too violent reaction.

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2\uparrow$$

Pass through small condenser and connect condenser with apparatus (SO_2 condenser) shown in FIG. 30, which is immersed in a freezing mixture (ice and salt). SO_2 is easily condensed by "*cold*" to a liquid. Turn stop-cocks and preserve.

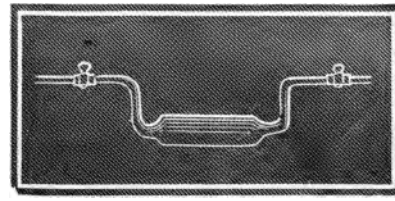


Fig. 30.—SO_2 Condenser.

Wire stop-cocks (FIG. 31) on rubber connectors (boiled in paraffine) may be used in place of glass stop-cocks. SO_2 may also be condensed in *strong* glass tube (drawn to a point at one end) by pressure of a

plunger with close fitting, greased rubber head. When pressure (at 15°) reaches one and one-half atmospheres, drops appear on the side, and liquid SO_2 gathers in the lower part of the tube. If plunger is quickly withdrawn a part is frozen (by cold produced by *sudden evaporation*) into a snow-white solid.

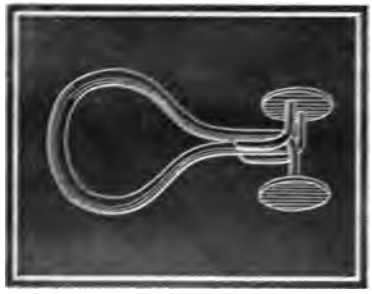


Fig. 31.- Spring Stop-Cock.

Place water in small platinum or other thin-walled dish and pour around it a little liquid SO_2. Blow with bellows to hasten evaporation of SO_2. The rapid vaporization produces a cold (—50°) so great (absorbs so much heat) that the water is quickly frozen. Mercury may be frozen if used instead of water. If SO_2 be evaporated in the receiver of an air-pump, a part will be solidified (frozen) forming snow-like solid.

EXP. 95.—Burn S in a large jar and pass into it H_2S (See EXP. 7). The bottom of the jar is covered with sulphur.

$$SO_2 + 2H_2S = S_3 + 2H_2O$$

This illustrates the formation of native sulphur *in volcanic regions*, as volcanic gases contain SO_2 and H_2S.

EXP. 96.—Burn S as in EXP. 3, and quickly stir with glass rod, upon the end of which is twine wet with strong HNO_3. (*Nitrates* are good *oxidizing agents*, we have learned). The SO_2 takes O from the nitric acid, becoming SO_3 sulphuric oxide (anhydride). Shake up with water.

$$SO_3 + H_2O = H_2SO_4$$

Test water with barium chloride, the test of sulphuric acid (and soluble sulphates).

$$H_2SO_4 + BaCl_2 = \underset{\text{white precipitate}}{BaSO_4} + 2HCl$$

Sulphuric acid, ("oil of vitriol") is an *oily liquid* (sp. gr. 1.84). It is the *most important* of the acids and is used in preparing numberless other substances, especially acids.

The experiment illustrates its preparation.

SO_2 from burning sulphur is carried into large leaden chambers, whose floors are covered with water. Into these air and nitric acid fumes are admitted. The N_2O_4 from the nitric acid acts as a carrier of O from the air to the SO_2 (see Exp. 38).

$$2SO_2 + N_2O_4 = 2SO_3 + N_2O_2$$

$$N_2O_2 + \underset{\text{from the air}}{O_2} = N_2O_4$$

The dilute acid is evaporated in leaden pans, till it begins to attack the lead. (Commercial $H_2\overline{SO_4}$ contains $Pb\overline{SO_4}$, which falls as white precipitate when the acid is diluted). It is then removed and concentrated in glass or platinum stills.

Exp. 97.—Into a beaker containing water pour twice its volume of strong H_2SO_4. Great heat is developed.

Exp. 98.—Upon white sugar ($C_{12}H_{22}O_{11}$) (starch or wood $C_6H_{10}O_5$) pour strong sulphuric acid. It chars by removing the elements of water, leaving the black carbon free. Evaporate dilute $H_2\overline{SO_4}$ upon white paper. As the acid increases in strength, the paper chars.

Concentrated sulphuric acid has a *great affinity for water*. It is used for drying gases with which it does not react. Care must be taken in diluting the acid, to mix in a vessel that will stand the **heat.** (In diluting heavy liquids, pour the liquid into the water, (not water into the liquid).—"*Fuming sulphuric acid*" is a solution of SO_3 in H_2SO_4.

Exp. 99.—Into a solution (slightly acidulated with **HCl**) of salts of lead, copper, bismuth, mercury (ic) cadmium, arsenicum, antimony, and tin respectively in test tubes, also into **Zn** salt, to which a few drops of ammonium hydrate have been added, put solution of H_2S. Reaction by change of partners throws down sulphides. **PbS** black, **CuS** black, Bi_2S_3 black, **HgS** white, yellow, reddish-brown, and finally black, **CdS** yellow, As_2S_3 lemon yellow, Sb_2S_3 orange, **SnS** brownish-black, SnS_2 yellow.

Hydrogen sulphide (H_2S "sulphuretted hydrogen") is

much used in the laboratory to precipitate metals, as sulphides (see ANALYTICAL CHARTS). H_2S is readily inflammable, as may be shown by igniting in test tube.

Carbon disulphide (CS_2) a volatile, colorless, inflammable liquid, may be produced by passing sulphur over red-hot coals. It is an excellent **solvent,** dissolving readily S, P, I, and many organic substances. It **refracts light** powerfully, and hence is often used in filling prisms.

The rare element, Selenium, in many respects resembles sulphur.

Phosphorus is a semi-transparent, nearly colorless, wax-like solid. It is kept under water in "sticks," as it slowly oxidizes in the air and takes fire at a very low temperature. It is highly poisonous. Its vapor breathed (in more than minute quantities) produces ulceration of the jaw, cured with difficulty (see CAUTION, EXP. 23).

Another variety, red or amorphous, is known. This differs widely from ordinary **P**. It does not emit the "jaw-poisoning fumes" and can be safely handled. **P** in this allotropic state may be prepared by heating ordinary phosphorus in a closed vessel.

Phosphorus, because of its low igniting point, is largely used in the manufacture of **matches.** The wood of the match is first dipped in melted sulphur, then into paste of P, potassium nitrate (or chlorate) for an oxidizing agent and glue (varnish). The P is kindling for the S, the S for the wood (hydrocarbon), while the nitrate furnishes the O for rapid combustion. The reactions in burning a match are:—

$$P_2 + O_5 = P_2O_5; \qquad S + O_2 = SO_2;$$
$$H_2 + O = H_2O; \qquad C + O_2 = CO_2.$$

"**Safety Matches**" contain no **P**, and ignite readily only when the chemicals of the match are rubbed on a surface of red phosphorus (and powdered glass to increase friction).

Phosphorus glows in the dark (its best test). Such glowing without heat is called **phosphorescence.** That of decaying wood and of putrifying fish is due to the presence of **P**.

EXP. 100.—Into a test tube half full of water drop several very small pieces of **P.** Cover **P** with fine crystals of $\mathbf{K\,\overline{Cl\,O_3}}$ (oxidizing agent). Allow several drops of concentrated $\mathbf{H_2\,\overline{S\,O_4}}$ to run down the sides of the test tube upon **P.** The **P** burns beneath the water.

A combustible element burns if raised to the igniting point in presence of free oxygen, or of an oxidizing agent. (In this case $\mathbf{Cl_2\,O_4}$ from the reaction).

Calcium Phosphate ($\mathbf{Ca_3\,2\,\overline{P\,O_4}}$) forms fully one-half by weight of bones, and is the source of **P.** "Superphosphate of lime" is a peculiar acid phosphate of calcium ($\mathbf{Ca\,H_4\,2\,P\,O_4}$). (See ADDITIONAL EXPERIMENTS).

CHAPTER XXV.

BORON AND SILICON.

Boron may be obtained from boron oxide $\mathbf{B_2\,O_3}$ as a *brown powder*, and also in yellowish-brown crystals. **Boracic acid** ($\mathbf{H_3\,\overline{B\,O_3}}$) is found in the lagoons of the volcanic regions of Tuscany. Jets of steam containing the acid issue from the earth and are absorbed by the water. This is afterward evaporated by heat from the jets leaving the crystallized acid. Boracic acid is also made from borax.

EXP. 101.—Upon copper (or iron) wire covered with a coating of the black oxide, melt a borax bead. The melted borax *dissolves* the oxide leaving the bright "metallic" copper.

Borax (sodium tetraborate, $Na_2\,\overline{B_4\,O_7}$, $10\,H_2\,O$) is used in welding and soldering because it dissolves the oxide of the metal, leaving the surfaces bright. (See HARD WATER.)

EXP. 102.—Dissolve borax* in a little alcohol ($\overline{C_2H_5}\ \overline{HO}$) and ignite. The flame has a peculiar *green* tint. This is a good test for the presence of a borate.

EXP. 103.—Dissolve copper oxide in borax bead in oxidizing flame of the blow-pipe. Color *green* when hot, *blue* when cold. Change to reducing flame, color, reddish-yellow. Dissolve in like manner cobalt oxide, bluish-black in oxidizing flame, intensely blue in reducing flame. Dissolve **Mn** O_2, intense reddish-violet in oxidizing flame, in reducing flame, almost colorless.

Borax is largely used in **blowpipe analysis** as a "flux" (see larger text books).

Silicon is, next to O, the most abundant element, though unlike O, it is always found combined (not free or native). The larger part of the earth's crust is silicon oxide, Si O_2 (sand, **quartz**), or silicates. Many precious stones (amethyst, agate, etc.) are quartz colored with some metallic oxide. Silicates of K and Na, absorbed by roots, give the stiffness and shining surface to corn stalks and the edge of "sword grass."

Petrifaction is the *replacement* of wood by stone (silicates). Certain silicates are *soluble* in water containing alkaline (**K, Na,** $\overline{H_3N}$) carbonates. As fast as the wood placed in the water decays, the silicate is deposited, and copies very precisely the lines of the wood (knots, grain, etc.).

Glass is a mixture of several silicates (as is also porcelain). Common window glass (**crown** or **plate glass**) is chiefly calcium and sodium silicates. **Ca** hardens and gives lustre. **Na** makes fusible, but gives greenish tint. **Bohemian glass** is chiefly **Ca** and **K** silicates, **K** gives no color. **Flint glass** is chiefly **K** and **Pb** silicates. This can be ground into imitation gems, prisms, etc. When very rich in lead it is known as "*paste.*"

EXP. 104.—Into separate pieces of soft glass fuse **Co O**, Cu_2O, **Mg O** (from EXP. 2), Fe_2O_3 (rust) respectively, the pieces are colored blue, ruby red, violet, and "bottle green."

*(*previously* moistened by drop of dilute sulphuric acid to liberate *boracic acid.*)*

Glass is **colored** any desired tint by fusing with a small quantity of some metallic oxide. "Purple of Cassius" (EXP. 115) is used for the finer ruby red; As_2O_3 gives the white, soft enamel of lamp shades, etc.

Glass is **annealed** by being cooled very gradually for days. When cooled quickly, it is very brittle. Lamp chimneys break from sudden change of temperature, because not properly annealed.

CHAPTER XXVI.

ARSENICUM, ANTIMONY, AND CHROMIUM.

Arsenicum (sp. gr. 5.7) is a brittle, steel-gray solid (semi-metal), generally found in combination. Two sulphides, yellow, As_2S_3 (arsenous sulphide, orpiment) and red As_2S_2 (realgar), occur native.

Caution.—Care must be taken in experimenting with arsenicum, as itself and its compounds are violently poisonous. Use very small quantities in all experiments, especially avoid breathing H_3As (see ANTIDOTES).

EXP. 105.—Place in a small glass tube, drawn out and closed at one end "white **arsenic**" (As_2O_3 arsenous oxide "**ratsbane**") of the bulk of a pin's head. Heat very gradually; the "arsenic" sublimes and condenses in minute, octahedral crystals in the upper and colder part of the tube. (Examine crystals with a lens). Perform the same experiment, placing above the arsenous oxide (anhydride) powdered charcoal and first raising the charcoal to low red heat. A dark mirror-like ring of arsenicum condenses upon the tube above, and a **garlic odor** is distinctly perceived.

$$2As_2O_3 + C_3 = 3CO_2 + As_4$$

EXP. 106.—Boil a few decigrams of "white arsenic" in water.

$$\underset{\text{acid-forming oxide or anhydride}}{As_2O_3} + \underset{\text{water}}{3H_2O} = \underset{\text{hydrogen arsenite (acid)}}{2H_3AsO_3}$$

Filter and preserve filtrate as a sample of an **arsenite**, this may be considered a solution of arsenous oxide. In EXP. 10). Place a centigram of As_2O_3 in ten drops of

having raised to the boiling point, evaporate over water-bath nearly to dryness. Dilute with water, filter and preserve as an example of an arsen**ate**.

1. As_2O_3 (arsenous oxide.) + O_2 (from nitric acid, an oxidizing agent.) = As_2O_5 (arsenic oxide.)

2. As_2O_5 (anhydride.) + $3H_2O$ (water) = $2H_3\overline{AsO_4}$ (acid.)

Exp. 107.—To copper sulphate solution (5 per cent.) add $\overline{H_4N}\ \overline{HO}$ till the precipitate formed is partially but not wholly dissolved. Filter, divide filtrate into two portions. To the first add drop by drop an arsen*ite*, a *green* precipitate of acid copper arsenite ($CuH\overline{AsO_3}$, "Scheele's Green," Paris green, etc., used as a pigment) falls. To the second portion add a few drops of an arsen*ate*, an acid copper arsenate ($HCu\overline{AsO_4}$) light blue to *green*, falls.

Exp. 108.—To silver nitrate solution (2½ per cent.) add $\overline{H_4N}\ \overline{HO}$ and proceed as in Exp. 107. From first portion *yellow* silver arsenite ($Ag_3\overline{AsO_3}$) falls; from the second portion a beautiful *chocolate* silver arsenate (Ag_3AsO_4) falls.

By the last Exp. an arsenite may be readily distinguished from an arsenate. The pupil may learn here that the chemist in analysis depends largely upon the **color of precipitates** as well as upon **solubility** (or insolubility) in various reagents. (See Exp. 109 and 113). Arsenic acid is used in preparing aniline red (for dyeing) and other arsenates (especially $Na_3\overline{AsO_4}$) are used in calico printing.

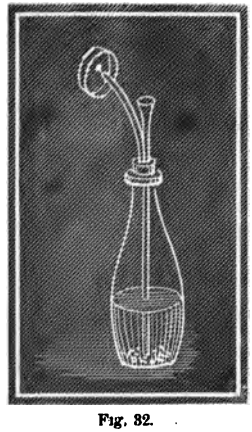


Fig. 32.

Exp. 109.—Into a flask prepared with safety-funnel as in Fig. 32, and containing **Zn**, pour dilute $H_2\overline{SO_4}$ and *after air is expelled*, ignite as with philosopher's lamp. If a cold porcelain dish is held in the flame moisture alone is deposited. Pour through the funnel a few drops of arsenical solution (*ate* or *ite*). The color of the flame changes and the cold dish is smutted with arsenicum. (Just as a candle-flame smuts a cold dish with **C**). Upon the mirror-like spot place a drop of hot, strong nitric acid, it dissolves. Upon a second spot place a drop of calcium chloride ("bleaching powder" answers), it dissolves. (Unlike the antimonial spot. See Exp. 113).

$$(1)\text{—}Zn + H_2SO_4 = Zn\overline{SO_4} + \acute{H}_2$$

$$(2)\text{—}\underset{\text{"nascent" hydrogen.}}{H_3} + As = \underset{\text{inflammable gas.}}{H_3\acute{A}s}$$

$$(3)\text{—}2\,H_3As + \underset{\text{from air.}}{O_6} = 3\,H_2O + As_2O_3$$

This last Exp. is **Marsh's test** for "arsenic" (any compound of arsenicum). Of course in all tests, the chemist must first make sure that his materials are pure, or at least free from the substance he is searching for in the unknown liquid or material. (See Magnesium). If a cold test-tube be placed over the arsenical flame, octahedral and characteristic crystals of As_2O_3 condense upon its sides.

Exp. 110.—Place a small piece of clean copper wire in arsenical solution acidulated with hydrochloric acid and boil. ($H\overline{NO_3}$ must not be present). Arsenicum is deposited on the copper. Wash, carefully dry and heat in closed glass tube; octahedral crystals of As_2O_3 are deposited. (**Reinsch's test**).

Exp. 111.—Generate hydrogen by heating to near the boiling point a strong solution of $Na\overline{HO}$ and Zn.

$$Zn + 2\,NaHO = Na_2\overline{ZnO_2} + \acute{H}_2$$

Add a few drops of a solution of "arsenic," and pass gas through wash-bottle of lead acetate solution to remove traces of H_2S; spread over mouth of wash-bottle filter paper moistened with $AgNO_3$.

$$H_3 + As = H_3\acute{A}s$$

$$H_3As + 3\,H_2O + 6\,Ag\overline{NO_3} = H_3\overline{AsO_3} + 6\,H\overline{NO_3} + Ag_6$$

The free silver turns the paper *purplish-black*. (**Fleitmann's test** distinguishes arsenicum *in presence of* antimony).

Arsenicum (and its compounds) is a powerful **antiseptic.** Bodies of those poisoned with it are sometimes preserved from putrefaction for years. In small doses it stimulates and causes persons to grow fat. In a certain district of Hungary the peasants habitually eat "arsenic." It is said to beautify the complexion, but its use is a very

dangerous practice. All the symptoms of arsenical poisoning appear, if one ceases the practice.

Antimony (sp. gr. 6.7) is a brittle, highly **crystalline** solid (semi-metal), with brilliant lustre. Upon the surface of its bluish-white masses are usually *fern-like crystallizations.*

EXP. 112.—Into an acidulated (**H Cl**) solution of antimony (tartar emetic, $\mathbf{K\overline{SbO}\ \overline{C_4H_4O_6}}$) potassium "antimonyl" tartrate) pass $\mathbf{H_2S}$ gas (or its solution). $\mathbf{Sb_2S_3}$, antimonous sulphide, falls. Filter, dry, and heat carefully; it turns greyish-black.

Native **antimonous sulphide** (gray antimony, or antimony glance) is the source of the **Sb** of commerce.

EXP. 113.—Perform experiment 109, using antimonial solution, instead of arsenical. Dark antimony spots are obtained. Upon one, place solution of calcium chloride, it is *unaffected;* upon another, place a drop of hot nitric acid, it is oxidized (turned white, $\mathbf{Sb_2O_3}$), but *not* dissolved.

Antimony is a constituent of several important alloys, as type metal, etc. (see ALLOYS).

An **alloy** is a mechanical mixture of two or more metals (including semi-metals). If one of the metals is mercury, the alloy is called an **amalgam.** A mechanical mixture differs from a chemical compound in that it may contain its constituents in *any* proportions, but a chemical compound must contain each constituent in some one proportion, or *multiple of that proportion.*

Chromium (sp. gr. 4.8) is a silver-white metal (considered **a metal,** though ordinarily negative to **H**). (Let the student learn right here, that the order of elements in Table No. 1 is the *usual* order. **Rarely** an element takes a different position when obtained by **electrolysis** under different circumstances, or from different compounds).

Chromium makes both acid-forming ($Cr O_3$) and basic ($Cr_2 O_3$) oxides with corresponding acid ($H_2 \overline{Cr O_4}$ chromic acid) and base ($Cr_2 6 \overline{H O}$) respectively.

The principal ore of chromium is "**chromic iron ore**" ($Fe Cr_2 O_4$). A few of its compounds are extensively used in the arts, viz.: potassium chromate ($K_2 \overline{Cr O_4}$) potassium bichromate (di-) ($K_2 \overline{Cr_2 O_7}$) and lead chromate ($Pb \overline{Cr O_4}$) "chrome yellow" (see ANA. CHARTS).

CHAPTER XXVII.

GOLD AND PLATINUM.

NOTE.—With this chapter we begin the study of the metals proper. In general, a **metal** is an elementary substance (1) with a peculiar lustre, called metallic, (2) insoluble in water, (3) a good conductor of heat and electricity, (4) positive, with reference to hydrogen, and (5) uniting with **H** and **O** to form bases. Chemists are not, however, agreed, as to any precise definition, and the line between metals and non-metals cannot be sharply drawn. This is the case with terms used in all sciences (except in the exact sciences, included in the general term mathematics). No line can be drawn between soluble and insoluble substances, for one kind fades gradually into the other. (Though **Pb** is considered insoluble, traces of the metal may be found in distilled water, that has been in a leaden dish for a day or two). So in physics, no line can be definitely drawn between "hot" substances and "cold" ones, but the terms are relative.

For uses of the metals, reduction of their ores, etc., see fuller accounts in the cyclopædia and in larger works on chemistry.

Gold (sp. gr. 19.3, fusing point 1100°) is found native (free), frequently alloyed with silver, in **quartz** veins, alluvial (by water) deposits, ("placers") etc. It is obtained by (1) **quartz mining,** (2) **placer mining,** and (3) **hydraulic mining.**

Exp. 114.—Dissolve a piece of gold leaf in globule of **Hg**. Place the amalgam on hard glass and in window with outward draft; keep at dull red heat for a little time. **Hg** distills leaving the gold.

Mercury is used to extract gold from the sands or from pulverized quartz. The amalgam of Au and Hg is then submitted to pressure in "bags," which squeezes out much of the Hg. The remainder is driven off by distillation, but the Hg is saved, not thrown away as in the experiment.

Gold is a very brilliant orange-yellow solid, the most ductile and malleable of the metals (280,000 sheets of the finest gold-leaf make only one inch in thickness). It was known as the "king of metals," and together with platinum and silver (also rare metals of platinum group) is called a **noble metal.** The others in contrast are called **base metals.** It is insoluble in any of the common acids, but dissolves in **"aqua regia,"** chlorine-water or bromine-water.

Pure gold is too soft for jewelry, coin, etc, and is hardened by copper. A carat is $\frac{1}{24}$. An alloy containing $\frac{16}{24}$ pure gold is said to be gold of 16 carats fine.

When gold is dissolved in aqua regia (Exp. 44), a solution of **auric chloride** ($AuCl_3$) is formed. (Evaporate to dryness over water bath, dilute, filter, and preserve filtrate as a solution of gold chloride). **Aurous cyanide** ($Au\overline{CN}$) dissolved in solution of $K\overline{CN}$ is used in electro-gilding.

Exp. 115.—(1) To a solution of an auric salt ($AuCl_3$) add H_2S. A brown precipitate of Au_2S_3 falls, soluble in $(\overline{H_4N})_2S$.

$$2\,AuCl_3 + 3\,H_2S = Au_2S_3 + 6\,HCl$$

(2)—To solution of salt of gold ($AuCl_3$) add ferr*ous* sulphate.

$$2\,AuCl_3 + 6\,\underset{\substack{\text{ferrous}\\\text{sulphate}}}{FeSO_4} = \underset{\substack{\text{free}\\\text{gold}}}{Au_2} + \underset{\substack{\text{ferric}\\\text{chloride}}}{Fe_2Cl_6} + 2\,\underset{\substack{\text{ferric}\\\text{sulphate}}}{Fe_2(\overline{SO_4})_3}$$

Boil precipitate in **HCl**, mix with equal bulk of borax and fuse in *strong* blowpipe flame. A "button" of pure gold is obtained.

(3)—Add a few drops of solution of stannous and stannic chlorides (**Cl** water put into **Sn** Cl_2 gives **Sn** Cl_4) to dilute solution of **Au** Cl_3, a purplish finely-divided precipitate, "purple of Cassius," (composition doubtful) falls. The same precipitate is slowly obtained, if tin foil is placed in solution of **Au** Cl_3.

Platinum (sp. gr. 21.5, fus. pt. 2000°) is found native usually alloyed ("platinum ore") with iron, copper, or some of the rare metals (*palladium* used to color "salmon" bronze, *rhodium*, *iridium* used to tip gold pens, *ruthenium* and *osmium*) of the platinum group. Like gold, it is insoluble in any one of the common acids, but dissolves in chlorine-water, and slowly in aqua regia, (H Cl + H $\overline{N O_3}$). Its "ore" is worked by means of the oxy-hydrogen blowpipe, coal gas being usually used in place of H.

Platinum is to the chemist an exceedingly useful metal. From it he makes crucibles, stills (see $H_2 \overline{S O_4}$), wire, blowpipe tips, etc.

Platinum sponge and **platinum black** (finely divided **Pt**) have the power of absorbing **O** and thus oxidizing easily oxidizible substances (ether, alcohol, hydrogen, etc.) brought in contact with it. (See ADD. EXP.)

CHAPTER XXVIII.

SILVER, MERCURY AND LEAD.

Silver (sp. gr. 10.5, fus. pt. 1040°) is found native often alloyed with copper, mercury and gold. Ag_2S (mixed with other sulphides as galena, PbS) and AgCl (**"horn silver"**) are among its chief ores.

EXP. 116.—Repeat EXP. 5, and place the resulting **AgCl**, mixed with a little K_2CO_3 (or Na_2CO_3) upon charcoal and heat in reducing flame of the blowpipe. A silver globule ("button") is obtained.

$$(1)—K_2CO_3 + 2AgCl = Ag_2CO_3 + 2KCl$$

$$(2)—Ag_2CO_3 = Ag_2O + CO_2$$

$$(3)—2Ag_2O + \underset{\text{deoxidizing agent.}}{C} = Ag_4 + CO_2$$

The melted globule absorbs oxygen from the air, and if cooled quickly the escaping **O** breaks the hardening surface, and the melted ("molten") silver runs out ("spitting" or "sprouting").

Silver is a brilliant white metal. For jewelry, coin, etc., it is hardened with Cu. It is used for silvering mirrors because it takes a *high polish*. It is not acted upon by fused caustic alkalies (KHO, NaHO, etc.), as glass and platinum are, and hence certain chemical vessels are made from the metal. It expands at the moment of solidification and hence can be cast (*copies fine lines of the mould*).

Silver is obtained from the sulphide by (1) roasting the pulverized ore with salt, $Ag_2S + 2NaCl = 2AgCl + Na_2S$, and (2) by placing the **Ag Cl** in a cylinder with H_2O, **Hg** and **Fe** scraps, $2AgCl + Fe = FeCl_2 + Ag_2$. The **Hg** forms an amalgam with silver from which the **Ag** is obtained, as gold is obtained from gold amalgam. The process of EXP. 116 is too expensive for the practical miner, though used by the assayer.

Silver may be freed from lead by fusing the alloy, and as **Pb** crystallizes first it may be skimmed out. This leaves a portion of the **Pb** which may be completely extracted by **cupellation.** (A **cupel** is a shallow dish made of bone ashes). The **Ag** containing **Pb** and other impurities is placed in the cupel and raised to the red heat. A hot current of air plays upon the fused mass. The **Pb** is oxidized and the **Pb O** is absorbed by the cupel. After a while the refiner sees the mirror-like globule of pure silver and quickly removes it lest it also oxidize and waste.

The most important salt of silver is the **nitrate** ($AgNO_3$, **lunar caustic**). It forms with organic compounds by the action of light a very stable, dark compound, and hence is used in **indelible inks** (see EXP. 89).

The changes which the salts of silver undergo when exposed to light, especially in presence of organic matter, is the basis of **photography** (see EXP. 5, NOTE).

EXP. 117.—Borrow an old "negative" from a photographer, and upon a sheet of prepared paper (moistened with silver salt and dried in the dark) furnished by him, print by means of a few moments exposure to direct sunlight a photograph. After a few hours exposure (even to reflected light), the picture fades out, because the entire paper turns black. [The photographer applies reagents to dissolve from the unblackened portion the silver salt, and thus preserves the picture. In preparing the negative he first covers the glass with an organic film (collodion) to receive the silver salts. (Hold a lens up between the window and a sheet of paper. The lens converges the rays of light and forms an inverted image of the window upon the paper. This explains the formation of the "negative" in the "camera"). After the formation of the image, he treats the slide (glass) with reagents whose action upon the part previously influenced by the light is different from their action upon the part uninfluenced by the light].

A solution of **Ag C N** in solution of **K C N** is used in electroplating.

Mercury or "**quicksilver**" (sp. gr. 13.5, fus. pt., *i. e.*, freezing point—39.4°) is found native in small quantities, but its chief source is the ore **cinnabar** (Hg S mercuric sulphide) from which the liquid metal is obtained by mixing with iron turnings (or lime) and distilling.

$$Hg\,S + Fe = Fe\,S + Hg$$

When **Hg S** is prepared artificially (by subliming together **S** and **Hg**) it is called **vermilion** and is used as a pigment.

Mercury is largely used in making thermometers, barometers, etc., for collecting gases soluble in water (see FIG. 29), for extracting gold and silver from their ores, for silvering mirrors (tin amalgam), and formerly was much used in medicine. "*Blue pill*" is **Hg** "rubbed up" with lard till the globules are not visible to the naked eye.

EXP 118.—Pour a little dilute nitric acid upon a considerable quantity of **Hg**, and bringing to boiling point, leave over night; pour off from the excess of **Hg** and preserve as solution of mercur*ous* nitrate ($Hg_2\,2\,N\,O_3$). Dissolve a small globule of **Hg** *completely* in an excess of hot, strong nitric acid. Evaporate nearly to dryness, dilute and preserve as solution of mercur*ic* nitrate ($Hg\,2\,N\,O_3$). (Of course these salts may be obtained dry by evaporation over a water bath).

EXP. 119.—To a solution of mercurous nitrate add **H Cl**.

$$Hg_2\,2\,N\,O_3 + 2\,H\,Cl = \underset{\text{white precipitate}}{Hg_2\,Cl_2} + 2\,H\,N\,O_3$$

Mercurous chloride (**calomel,** $Hg_2\,Cl_2$) is an insoluble, (in water) white powder. It acts powerfully upon the glandular system (liver, etc.), and in large or long continued doses produces **salivation** (excessive action of the salivary glands) and other serious results. It was formerly much used in medicine, by some almost as a "cure all."

EXP. 120.—To a solution of mercuric nitrate add **H Cl**.

$$Hg\,2\,N\,O_3 + 2\,H\,Cl = Hg\,Cl_2 + 2\,H\,N\,O_3$$

There is no precipitate because $Hg\,Cl_2$ is soluble. Place a drop of the solution on glass and evaporate at *low heat*. White crystals of $Hg\,Cl_2$ are obtained.

Mercuric chloride ($HgCl_2$ **corrosive sublimate**) is a powerful poison and a strong **antiseptic.** It is used to prevent the decay of wood and its dilute solution in alcohol brushed over specimens in Natural History preserves them (see ANTIDOTES).

EXP. 121.—In a solution of salt of **Hg** place a clean (by HNO_3 and afterward H_2O) copper wire. It is soon coated with a mirror of **Hg**, more apparent if dried by blotting paper and gently burnished with soft cloth. An equivalent amount of copper passes into the solution to take the place of the displaced **Hg.** Cut off the mirrored end of the wire, and, placing in closed glass tube, heat. **Hg** distills and globules of the metal gather upon the sides of the tube.

In almost any solution containing soluble compound of **Hg**, it may be detected by this *test.* No test for **Hg** should be considered complete, unless metallic globules are obtained. A lens will often reveal the globules, if the amount of mercury is exceedingly small.

EXP. 122.—To mercur*ous* nitrate add **KI**, *green* mercur*ous* iodide (Hg_2I_2) falls. To mercur*ic* nitrate add **KI**, red mercuric iodide (HgI_2) falls (EXP. 9). Wash, dry, place in cold tube, and sublime. HgI_2 condenses on the sides of the tube in *yellow* crystals; rub crystals with stick, they change to the original *red.* This change of color may be repeated indefinitely.

NOTE.—It will be noticed that **Hg** forms two classes of salts, *ic* (Hg = dyad), and *ous* (Hg_2 = dyad). The same is true of **Cu.** Iron in *ous* salts makes **Fe** = dyad, in *ic* salts Fe_2 = hexad. Aluminum forms but one class of salts, but all molecules of aluminum compounds contain at least two atoms of **Al**, and Al_2 = hexad (see REF. TABLE, No. 1).

Lead (sp. gr. 11.4, fus. pt. 334°) is rarely found free. Its chief ore is lead sulphide (Pb S, galena), often carrying Ag_2S. The roasting ("smelting") of this ore and separation of the metal is a very simple process. Pb is soft and malleable, and when fresh cut has a lustrous bluish-gray color, quickly dulled by oxidation. Its common uses are well known to every school boy. It contracts in solidifying, and hence cannot be cast (*i. e.* to copy the fine lines of the mould).

EXP. 123.—Make two moulds by boring conical cavities into plaster of Paris ($CaSO_4$, $2H_2O$) and making fine, clean-cut grooves on the sides. Into one pour melted lead. Into the other pour melted lead, in which a little **Sb** and **Sn** has been previously dissolved (type metal). The first casting is blunt and does not copy the grooves; the second is sharp, pointed, and copies the grooves accurately. This is caused by expansion of the *crystalline* **Sb** and **Sn** in solidifying.

Water used for drinking purposes should not be brought great distances in lead pipes (unless the water contains considerable quantities of carbonates or sulphates, which coat the lead with white coat), and water that has stood over night in the short lead pipe connecting with faucet should be allowed to run out before drinking. Water containing even minute quantities (and otherwise practically harmless) of ammoniacal salts (from decomposition of organic matter) dissolves lead and keeps the surface *bright*. Chronic lead poisoning is produced by drinking such water. Lead is an "accumulative" poison, *i. e.*, it remains in the system and is thrown off with difficulty. Painters are often attacked by "colic" produced by lead poisoning.

Fruit cans should not be soldered with an alloy of **Pb** (See EXP. 127 and connection). Metallic **Pb** is not poisonous (Plumbers are not attacked by "lead colic").

Litharge (**PbO**) (see EXP. 50), "red lead" (Pb_3O_4) "**sugar of lead**" (lead acetate $Pb(C_2H_3O_2)_2$) and "**white lead**" (chiefly $PbCO_3$) used in painting, are important compounds. All are poisonous, especially the very soluble acetate (See ANTIDOTES, ALSO EXP. 11).

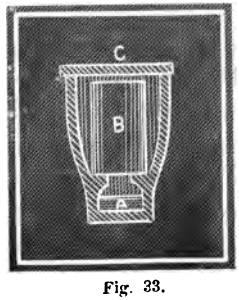


Fig. 33.

White lead is made as represented in Fig. 33. A roll of lead (B) is placed in an earthen vessel, and below, weak vinegar (A). Above (and around) is packed decaying tan bark (C) and refuse. These vessels are arranged in immense piles, the heat of the decomposition assists the evaporation of the vinegar and in five or six weeks the lead is all converted into $PbCO_3$

$$Pb + \underset{\text{from air}}{O} + \underset{\text{from vinegar}}{HC_2H_3O_2} = \underset{\text{basic salt}}{PbHOC_2H_3O_2}$$

$$\underset{\text{from decomposing refuse}}{CO_2} + \underset{\text{basic lead acetate}}{PbHOC_2H_3O_2} = \underset{\text{"white lead"}}{PbCO_3} + \underset{\text{unites with another portion of Pb}}{HC_2H_3O_2}$$

White lead is largely adulterated with gypsum ($CaSO_4 2H_2O$) heavy spar ($BaSO_4$) etc. (Pure $PbCO_3$ dissolves *completely* in hot dilute HNO_3)

EXP. 124.—Add a little mucilage to lead acetate solution (sympathetic ink) and write with fine hand a few words. Dry; they are invisible. Moisten the paper and allow H_2S gas to come in contact with it. The letters become black (see EXP. 8).

H_2S is a test for lead and *vice versa* lead acetate (paper moistened with it) is a test for H_2S. *"A body acted upon characteristically by a reagent is as good a test for the reagent, as the reagent is for it."—Attfield.* (see test in ANA. CHARTS).

CHAPTER XXIX

Cu, Fe, Zn, and Sn.

Copper is found free in large masses (Lake Superior mines). Its most common ore is copper pyrites (Cu S, and Fe S mixed), from which it is obtained by roasting with a silicate to remove the iron as iron silicate, and again roasting the Cu S. It is a reddish metal, highly malleable and ductile. With the exception of Ag it is the best conductor of heat and electricity. Brass, bronze, and bell-metal contain Cu (see ALLOYS).

The salts of copper are poisonous (see ANTIDOTES). Substances containing acids (fruits, jellies, pickles, etc.) should never be put in copper (or brass) utensils. Fats

dissolve copper oxide, and therefore should be put into copper dishes only when the vessels are bright. Copper sulphate ("blue vitrol," "blue stone" $CuSO_4 5HO$) is used in dyeing, calico printing and in galvanic batteries (see Exp. 34). The native malachite ($CuCO_3 + Cu2HO$) takes a high polish and is used for jewelry and other ornamental articles. Verdigris is copper acetate ($Cu2C_2H_3O_2$) though the name is often applied to the artificial carbonate.

Exp. 125.—Into solution of a copper salt (as $CuSO_4$) put a piece of clean iron. It is coated with copper, an equivalent amount of iron passing into solution.

$$CuSO_4 + Fe = FeSO_4 + Cu \text{ (deposited on iron).}$$

Exp. 126. Add H_4NHO to cupric solution, a characteristic *blue* precipitate soluble in excess of H_4NHO is obtained.

$$CuNO_3 + 2H_4NHO = 2H_4NNO_3 + \underset{\text{precipitate}}{Cu2HO}$$

(See NOTE Exp. 122.)

Iron (sp. gr. 7.8, fus. pt. 1000° to 1800°) is the most important of all the metals. It is rarely found free (always in aerolites) but in combination it is widely distributed, traces being found in the blood of animals and in the juices of plants. It is a soft, silver-white metal (if pure). Among the most important of its numerous ores are Fe_2O_3 ("specular iron," hematite), $Fe_2 6HO + Fe_2O_3$ (brown hematite, limonite, Fe_3O_4 ("magnetic iron") and $FeCO_3$ (spathic iron, ferrous carbonate). The value of the ore depends as much upon the nature of its impurities as upon the percentage of iron.

The old process of reduction ("Direct Process") was to roast the ore with charcoal in an open "forge" fire. The pasty mass of reduced iron, called "bloom," separates from the fused silicates (or fused glass), called "slag."

The modern process ("Indirect") consists of two parts, (1) obtaining

the reduced iron from the ore, not pure, but containing a large percentage of **C**. (This is cast iron, or "**pig iron.**"). (2) The production of iron nearly free from **C** ("**wrought iron**") from the cast iron.

1. The ore is placed in a "blast furnace" with layers of coal, coke, and "flux," [the last, limestone **Ca C** $\mathbf{O_3}$, if impurities are silicates (clayey), and silicates, if the impurities are calcareous. Of course, the object is to form a "slag" of calcium glass.] Hot air is driven in below. The heat of the furnace is intense and its action continuous. The "life" of the furnace fire is often twenty years, fresh material being ceaselessly supplied from above. The melted iron and "slag" (floating on iron) is drawn off below. [The hot **C** $\mathbf{O_2}$ (and unburnt gases), passing from chimney, are utilized for heating the air driven in below]. The iron runs into a large main, called "sow," and thence into lateral moulds called "pigs" (hence "pig iron").

2. **Pig iron** (2 to 5 per cent. of **C**) is changed to wrought iron (less than $\frac{1}{2}$ per cent. of **C**) by burning out the **C** (also **S**, **Si** and **P**) in a reverberatory furnace, "puddling furnace" (Fig. 34). Fuel burns upon the grate A, pig iron is placed upon the floor B, and is frequently stirred by means of openings in the side.

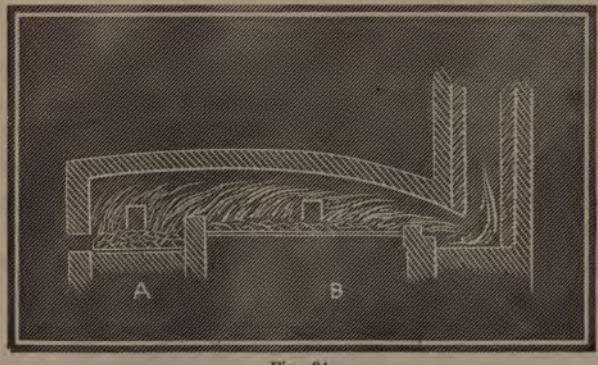


Fig. 34.

Steel contains more C than wrought iron and less than cast iron. It may be made by heating bars of wrought iron to redness in contact with powdered charcoal for eight or ten days. This is called the cementation process.

Bessemer steel is made by decarbonizing the best pig

iron at a fearful heat in an egg-shaped vessel (*"converter"*) lined with infusible material. Hot air is driven in below through numerous openings by means of a powerful engine. P, Si and S are also removed. "Looking-glass" iron containing a known quantity of C and a little Mg is then added. Bessemer's process is a rapid one. Bessemer's steel is largely used in constructing railroads, bridges, etc. Steel expands at the moment of solidification and therefore can be cast. Few metals besides iron can be welded. (To be welded a metal must soften before melting. Cast-iron cannot be welded). Iron (or its salts) is largely used in medicine as a tonic.

Ferrous sulphate (**$FeSO_4$, $7H_2O$**, green vitriol, copperas) is used in dyeing, making ink, etc. **FeS** is used in preparing the reagent **H_2S** (EXP. 7). Iron disulphide (**FeS_2, iron pyrites,** fool's gold) may be readily distinguished from gold by heating and observing the odor of **SO_2**.

Zinc (sp. gr. 6.9, fus. pt. 410°) very rarely occurs native. Its chief ores are Zn CO_3 (smithsonite), Zn S (Zinc blende) and Zn O ("red zinc ore" colored red by an oxide of Mn). It is bluish-white crystalline metal. Fe dipped in melted Zn is coated with the metal and forms what is improperly termed **galvanized iron**. Water that has stood a long time in zinc-lined vessels (tanks) is unfit to drink. Zn O (zinc white) is used as a pigment. (See ALLOYS).

Tin (sp. gr. 7.3, fus. pt. 230°) is obtained from its principal ore SnO_2 (tin binoxide, stannic oxide, **"tin stone"**) by roasting with carbon in reverberatory furnace. It is a lustrous, white, highly *crystalline* metal, malleable and ductile. When a bar of tin is bent, a crackling sound,

(*"tin cry"*) caused by the friction among the crystals, is heard.

"Tin ware" is really iron ware coated with Sn (dipped in the melted metal). When the tin wears off, the iron rust (Fe_2O_3, or hydrated $Fe_2 6HO$) is seen. Tin is often adulterated with (the cheaper) lead. Fruit, contained in cans coated with such "tin" is unfit to eat, for it contains poisonous lead salts. Pb is easily detected by

EXP. 127.—Upon a piece of tinned iron ("tin") place a drop of **HNO_3** and evaporate to dryness. Add a drop of **KI** solution, *yellow* **PbI_2** is formed, if lead is present.

$$Pb2NO_3 + 2KI = 2KNO_3 + \underset{\text{yellow}}{PbI_2}$$

Pins made of brass wire, copper utensils, iron tacks, etc., are covered with a thin coat of tin to give bright surface. Tin is largely used in making alloys (which see).

Tin bisulphide (**SnS_2**) a bright golden-yellow, is known as **mosaic gold,** and is used in decorative painting. **$SnCl_2$** (stannous chloride) and **$SnCl_4$** (ic) are largely used in dyeing.

CHAPTER XXX.

Bi, Co, Ni, Mn, Al, and Mg.

Bismuth (sp. gr. 9.8, fus. pt. 264°) is a brittle, purplish-white, crystalline metal. It forms alloys with other metals, expanding much in solidifying and *remarkable for their low melting point.*

EXP. 128.—Fuse **Bi** (5 dcg.), **Pb** (3 dcg.) and **Sn** (2 dcg.) together. The alloy is **fusible metal** (one variety). Place the cold globule in water and raise to the boiling point. Notice that the alloy melts (at 91.6°) before the water boils.

Fusible metal is used for taking casts of wood cuts, etc. Fusible metal (of different composition and melting at some definite point above 100°), is used for "safety plugs" in steam engines. When the temperature approaches a point that would be dangerous, the plugs melt and let the steam escape.

Cobalt (sp. gr. 18.6) is a silver white metal. Its salts (acetate, sulphate, nitrate, chloride), are used for sympathetic ink (see clyclopædia).

EXP. 129.—Divide a solution of cobalt chloride into two parts. Thicken each with a little pure mucilage. To one add a few drops of a salt of nickel. Write with a fine pen upon slightly pinkish papers. The writing is invisible. Heat each paper upon metallic support. The ink containing nickel is distinctly *green*, the other distinctly *blue*. [Moisture absorbed from the air changes *blue* **Co Cl_2** to a pale pink almost invisible even upon white paper]. The ink becomes invisible again when the papers cool.

Nickel (sp. gr. 8.9) is a lustrous white metal, taking a high polish. It is used for plating iron to protect from rusting. It is largely used in alloys.

Manganese (sp. gr. 8, fus. pt. about 1800°) is a hard brittle metal. It easily oxidizes in the air and hence is not found free. It is best kept under petroleum.

Manganese dioxide (**MnO_2**, see preparation of **O** and **Cl**) is its most important ore. **Manganates** (grouping **MnO_4''**) and **permanganates** (grouping **Mn_2O_8''**) are largely used as disinfectants.

EXP. 130.—Filter (through paper) water holding small quantities of decomposing organic matter in solution, (water shaken up in bottle from EXP. 60 answers well), and let fall into it a few drops of *very dilute* potassium permanganate (**$K_2Mn_2O_8$**). Place beside it a second test tube of distilled water in which the same amount of permanganate has been put. Leave both over night. The permanganate in the first test tube is decolorized having given up a part of its **O** to the organic matter. In the second the color remains. [The presence of ferrous salts, or other easily oxidizable substances, must be avoided].

Potassium permanganate is a powerful oxidizing agent and is a very delicate test for the presence of decomposing organic matter. [In

such tests be careful not to add too much $K_2 Mn_2 O_8$ as of course the excess would not be decolorized].

Aluminum (or aluminium, sp. gr. 2.6) is a bluish-white metal, taking a bright polish. It does not readily oxidize in the air. It would be very extensively used, if it were not for its high price. Delicate, light weights, and, in general, instruments needing lightness and moderate strength are made from aluminum.

Aluminum bronze (**Cu** 90 per cent., **Al** 10 per cent.) is a very hard alloy, malleable, has the color of gold and takes a fine polish.

$Al_2 O_3$ occurs in corundum, ruby, sapphire and emery (impure). Common **clay** is chiefly aluminum silicate, $Al_2 Si_2 O_7$, (there are numerous silicate "groupings"), but no cheap way of obtaining the metal has yet been discovered. Common **alum** is a double sulphate ($Al_2 K_2 4 S O_4, 24 H_2 O$) containing much water of crystallization. Ammonium alum ($Al_2 (H_4 N)_2 4 S O_4, 24 H_2 O$) is also somewhat common. Alum is much used in dyeing as a "mordant" (see DYEING). Cryolite is $Al_2 F_6 + 6 Na F$.

Magnesium (sp. gr. 1.75, fus. pt. about 2000°, but igniting point is low, the flame of a candle being sufficient to set it on fire) is a silver-white metal not found native, but in combination is widely distributed. Mg burns in the air with a brilliant light (EXP. 2), forming Mg O (magnesia. In general, the ending *a* means (1) the oxide, (2) the carbonate, (3) the hydrate of the metal). Its light is rich in chemical (actinic) rays, and hence is used for photographing in dark caves, etc. Arsenicum is never found with it, and the metal is used instead of Zn in important tests for As (see Marsh's test).

$Mg Cl_2$ is found in sea water. $Mg S O_4, 7 H_2 O$ (Epsom salt) is found in many mineral waters. "Magnesia alba" is an artificial mixture of $Mg C O_3$ and $Mg 2 H O$, principally the former. (See magnesite, hornblende, meerschaum, soapstone, talc, serpentine, dolomite, etc., in cyclopædia).

CHAPTER XXXI.

CALCIUM, STRONTIUM, AND BARIUM.

Calcium (sp. gr. 1.58) is a light-yellow ductile metal. It oxidizes in moist air and consequently is not found native (free). Its compounds are widely diffused,

Calcium oxide [Ca O, quicklime, a basic oxide (EXP. 4)] is prepared by heating the native carbonate ($CaCO_3$) in "kilns" till CO_2 is all expelled.

$$CaCO_3 = CaO + CO_2\uparrow$$

It is used for making mortar, cements, etc.

$$CaO + H_2O = \underset{\text{"water slacked lime," mortar}}{Ca(OH)_2}$$

When exposed to the air, this absorbs CO_2 and hardens.

$$\underset{\text{"water slacked lime"}}{Ca(OH)_2} + \underset{\text{from air}}{CO_2} = \underset{\text{"air slacked lime" dried mortar}}{CaCO_3} + \underset{\text{evaporates}}{H_2O}$$

Ca O falls to a powder when gradually air-slacked by exposure. It first absorbs water and then **CO_2** as in above reactions.

Ca O is used in the laboratory for drying gases (EXP. 45, 56, and illuminating gas) and in the "lime light," the flame of the oxy-hydrogen blowpipe raising it to the *white heat* and causing it to emit an intense light.

Calcium carbonate (**$CaCO_3$**) is found as marble, limestone, shells, (chalk is formed by beds of tiny shells), stalactites, etc., also with **$Ca_3(PO_4)_2$** in bones (see HARD WATER and EXP. 51). **$CaSO_4$** (anhydrite, calcium sulphate) and **$CaSO_4, 2H_2O$** (gypsum, plaster, alabaster) occur native. When heated to 120°, gypsum parts with its water of crystallization, forming "**plaster of Paris.**" This plaster

soon hardens ("sets") when mixed with water and hence is used as cement, and for taking casts. (See WATER permanently hard). **Ca Cl$_2$** has so strong an attraction for water, that it is deliquescent. It is used for drying gases. (See BLEACHING POWDER).

Barium (sp. gr. 4) and **Strontium** (sp. gr. 2.5) resemble calcium.

Fig. 35.—Green Fire.

EXP. 131.—Dissolve a barium salt in a little dilute **H Cl** and making a loop with platinum wire introduce into the lower and outer flame of Bunsen's burner. The flame is colored *green.*

EXP. 132.—Pulverize separately with great care **Ba 2 N O$_3$** (oxidizing and coloring agent) **K Cl O$_3$** (oxidizing agent) and gum shellac, (**C** and **H** principally, combustible body). Mix carefully and thoroughly equal bulk of each upon piece of paper. Place in small mortar and ignite using the paper as a fuse. It gives *green* fire.

Barium salts are used to give the color in **green** fire [in pyrotechny] and this color is a very good test for soluble or volatilizable salts of Ba.

Heavy spar (**Ba S O$_4$**) is often used to adulterate white lead (**Pb C O$_3$**). **Ba Cl$_2$** is test for soluble sulphates. (EXP. 96.)

EXP. 133.—Repeat EXP. 131, using **Sr** salt instead of **Ba** salt. The flame is colored *red.*

EXP. 137.—Repeat EXP. 132, using **Sr 2 N O$_3$** instead of **Ba 2 N O$_3$**. *Red* fire results.

Strontium salts are used to give the color in **red** fire, and this color is a very good test for soluble or volatilizable salts of Sr.

CHAPTER XXXII.

POTASSIUM, SODIUM, AMMONIUM.

Potassium (sp. gr. .87, fus. pt. 63°) is a light, bluish-white metal, soft enough (at 15°) to be spread with a knife.

EXP. 135.—Cut a small piece of clean **K** and throw upon water in beaker, covering with glass plate (impurities cause spattering.)

The affinity of K for O is so great that it must be kept under naptha ($C_{10}H_{16}$ containing no O). EXP. 135 proves that it cannot be found free or native.

The compounds of **K** are widely distributed. They are constituents of all plants and of the bodies of animals. **K H O** ("**caustic potash**") is a *white solid* made from K_2CO_3 by action of **Ca 2 H O** (and heat).

$$K_2CO_3 + Ca2HO = 2KHO + CaCO_3$$

It is largely used in the manufacture of soap. It is one of the strongest alkalies known. (See SOAP and ANTIDOTES).

K_2CO_3 ("**pearlash**") is prepared by leaching wood ashes, evaporating the "**lye**" in large pots (hence potash), and purifying by crystallization. It is a deliquescent salt, with a strong alkaline reaction. It (or Na_2CO_3) is largely used in chemical analysis. [See ANA. CHARTS, silver, lead, etc.] It reacts with insoluble silicates by change of partners.

The metallic silicate (insoluble) + potassium carbonate = potassium silicate + The metallic carbonate (soluble.)

$HKCO_3$ (**bicarbonate of potash, "saleratus,"** acid salt with alkaline reaction) may be prepared by passing CO_2 through strong solution of the normal salt (K_2CO_3).

$$H_2O + CO_2 = H_2CO_3$$
$$K_2CO_3 + H_2CO_3 = 2HKCO_3$$

Potassium nitrate (**K N O$_3$ saltpetre, nitre**) is formed by the decomposition of refuse organic matter. The white incrustation often seen about such matter is principally **K N O$_3$**. It is a strong **antiseptic,** and is used with **Na Cl** (common salt) for preserving meat. It is largely used in the manufacture of gunpowder. When gunpowder burns, the reaction may be represented thus :—

$$\underset{\text{solid oxidizing agent.}}{2\,K\,N\,O_3} + \underset{\text{solid combustible substance.}}{S} + \underset{\text{solid combustible substance.}}{C_3} = \underset{\text{gas at temperature of explosion.}}{K_2S} + \underset{\text{gas.}}{N_2} + \underset{\text{gas}}{3\,C\,O_2}$$

Fireworks are composed of gunpowder containing an excess of **C** and **S** with coloring matter.

Potassium chlorate (**K Cl O$_3$**) is a good oxidizing agent. (Exp. 80 and 100, and Matches.) **K$_2$ Cr$_2$ O$_7$** forms chrome yellow with lead salts. (Ana. Charts.) The intensely poisonous **K C N** dissolves gold and silver cyanides for electroplating.

K Cl resembles **Na Cl.** Potassium salts are largely used in medicine.

Sodium (sp. gr. .97) is a light, silver-white, soft metal.

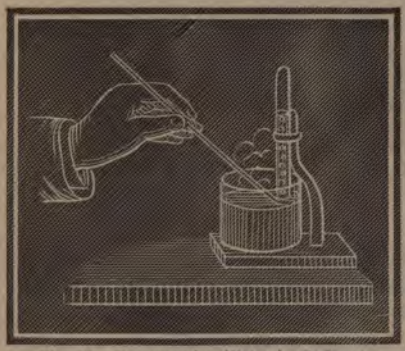


Fig. 36.—Decomposing Water by Sodium.

Exp. 136.—Place a small clean piece of **Na** on water and quickly press below mouth of inverted test tube by means of wire gauze attached to wire. The water is decomposed and the **H,** set free, collects in test tube. (If **Na** is thrown on hot water the liberated **H** immediately takes fire.)

$$Na + H_2O = Na\,H\,O + \overset{\nearrow}{H}.$$

Sodium resembles K. It is not found free and must be kept under naptha. It is used as a reducing agent in preparing Si, B, Mg, and Al. Sodium imparts a *yellow* tinge to flame.

EXP. 137.—Repeat EXP. 131, **using sodium salt and potassium salt respectively instead of barium salt. Sodium gives *yellow* and potassium *purple* flame.**

Sodium chloride (**Na Cl**, common salt) **is the most abundant** of the sodium compounds. It is the source from which most compounds and sodium itself are obtained. Its distribution in larger or smaller quantities is almost universal, traces which the spectroscope reveals being found in the atmosphere. It is obtained from immense deposits or beds, from saline springs and sea-water (by evaporation). It crystallizes in cubes [Chap. XXXIII]. It is one of our most common **antiseptics.**

Sodium sulphate (**$Na_2SO_4 10H_2O$**, Glauber's salts) **is remarkably** efflorescent.

Sodium carbonate (**$Na_2CO_3 10H_2O$**, sal soda) **is extensively** used in the arts. It is made by **Leblanc's process:—**

(1.) Common salt and sulphuric acid are heated,

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl\uparrow$$

The hydrochloric acid is saved by being absorbed (See EXP. 75, 76, and comments) in tower of coke wet with constantly falling water.

(2.) The **Na_2SO_4** is heated with **$CaCO_3$** (equal wt.) and **C** (half its wt.) in a reverberatory furnace.

$$\text{(a.)}\ Na_2SO_4 + \underset{\text{reducing agent.}}{C_2} = Na_2S + 2CO_2\uparrow$$

$$\text{(b.)}\ Na_2S + CaCO_3 = \underbrace{Na_2CO_3 + \underset{\text{insoluble}}{CaS}}_{\text{"black ash."}}$$

The **Na_2CO_3** is then washed out (**lixiviated**) from the "**black** ash" and purified by **crystallization** (one of the most valuable known means of purifying crystallizable solids).

Acid sodium carbonate (**HNaCO₃**, bicarbonate of soda, "**soda**" of cook-room) has alkaline reaction, and is prepared by passing **CO_2** into the normal salt (see **HKCO₃**).

Sodium hydrate (**NaHO**, caustic soda) is made from sodium carbonate (just as **KHO** from **K_2CO_3**) and is used in the manufacture of hard soap.

Sodium nitrate (**$NaNO_3$**, Chilian saltpeter) is a deliquescent salt.

Ammonium (H_4N, a hypothetical metal), as we have seen, is a compound radical, closely allied to K and Na. It has never been isolated. Its salts ($H_4N\,Cl$, sal ammoniac, $H_4N\,NO_3$, $(H_4N)_2\,CO_3$), etc., and its hydrate ($H_4N\,HO$, "ammonia water") are well known compounds (EXP. 37, 45, and ANTIDOTES).

CHAPTER XXXIII.

THE ALLOYS, SPECTRUM ANALYSIS, AND SYSTEMS OF CRYSTALLIZATION.

The most important **alloys** (with their usual proportions) are:—

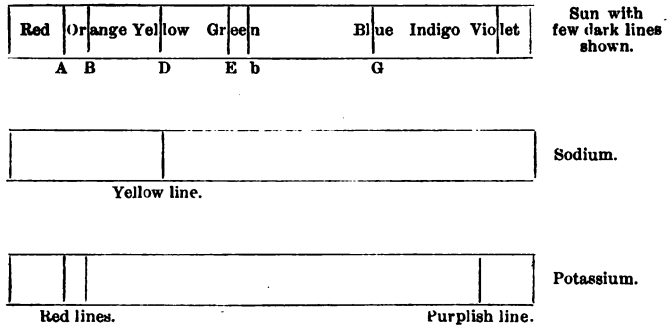
Aluminum Bronze.....**Cu** (9) **Al** (1)
Bell-Metal.....**Cu** (9) **Sn** (2)
Brass.....**Cu** (2) **Zn** (1)
Bronze.....**Cu** (95) **Sn** (4) **Zn** (1)
Coin (Gold).....**Au** (90) **Cu** (9) **Ag** (1)
Coin (Silver).....**Ag** (9) **Cu** (1)
Fusible Metal .....**Bi** (see) **Pb Sn**
German Silver.....**Cu** (5) **Zn** (2) **Ni** (2)
(brass)
Hard Solder.....**Cu** (1) **Zn** (1)
Pewter.....**Sn** (4) **Pb** (1)
Phosphor-Bronze.....**Cu** (88) **Sn** (10) **P** (1.5) **Pb** (.5)
Shot.....**Pb** (99.5) **As** (.5)
Soft Solder.....**Pb** (1) **Sn** (1)
Type-Metal.....**Pb** (70) **Sb** (20) **Sn** (10)

The **spectroscope**, next to the balance, is the most useful instrument for original chemical research. It consists of a **prism**, mounted upon a stand, carrying a tube with fine, adjustable slit, through which light (the rays being made parallel by a lens) falls upon the prism. The

light, refracted by the prism, is received by a small telescope, which magnifies the **spectrum** ("rainbow," if solar spectrum, *i. e.*, if light is sunlight) before it reaches the eye. The spectrum of the sun has dark lines (**Fraunhofer's lines**), crossing it at right angles all along from the red to the violet portion, but at irregular intervals. The relative position of these lines has been accurately determined.

If, instead of sunlight, the light from the sodium flame (EXP. 137) enters the slit no colored bands from red to violet, as in the solar spectrum, are seen. Instead, the spectrum is totally dark except a brilliant *yellow* line (double) crossing the spectrum where before (in solar spectrum) was the dark line D (double). If the light of the potassium flame enter the slit, three lines appear on the dark spectrum: a bright purplish line at (what was before) the violet end, and at the other end two red lines—the outer, bright; the inner, faint.

Spectra of



All the other metals and non-metals have characteristic spectra, but some substances require more heat than the flame of the Bunsen's burner to volatilize them, and the electric flame is used. With a small spectroscope the student can easily obtain the spectra of **Na, K, Ba, Sr, Co,** and other metals whose chlorides are easily volatilized. Many rare metals have been discovered by means of the spectroscope (caesium, rubidium, thallium, indium, etc.). By it the light of the heavenly bodies reveals the presence in those far-off suns of many elements common upon the earth (Celestial Chemistry).

Most chemical substances, when they pass from the liquid to the solid state, assume some definite form and are said to **crystallize** (see Exp. 34 and connection). It has been found possible to arrange all crystals in **six systems**, according to the arrangement of their sides and angles around certain imaginary **axes**, intersecting at the center of the crystals. These axes are shown only in Plates I and II of Fig. 37.

1. **Regular System.**—Three axes all *equal* and all at *right* angles. Plates I, II, and III. Ex.: Common salt, alum, garnet.

2. **Hexagonal System.**—Four axes, three equal and in one plane, making angles of 60°, and one, longer or shorter, at right angles to the plane of the other three. Plates IV and V. Ex.: sodium nitrate, quartz, and ice.

3. **Quadratic System.**—Three axes all at right angles, and one shorter or longer than the other two. Plates VI and VII. Ex.: Potassium ferrocyanide and tin dioxide.

4. **Rhombic System.**—Three axes all unequal and all at right angles. Plates VIII and IX. Ex.: potassium nitrate, barium sulphate, and sulphur, *crystallized from solution in carbon bisulphide.*

5. **Monoclinic System.**—Three axes all unequal. Two cut each other obliquely, and one is at right angles to the plane of the other two. Plate X. Ex.: Sodium carbonate, sodium phosphate, ferrous sulphate, borax, cane sugar, and sulphur *from fusion.*

6. **Triclinic System.**—Three axes, all unequal and all oblique. Plates XI and XII. Ex.: copper sulphate, manganese sulphate, boracic acid and potassium bichromate.

Certain substances, like S, crystallize in two systems, and are said to be *dimorphous.* A very few substances are trimorphous. Anything without crystalline form is *amorphous* (as *plastic* sulphur). Different substances that crystallize in the same form are *isomorphous* (as compounds of the halogens with the same metal). A crystalline body splits more readily in a certain direction than others. This splitting is called *cleavage.* The powder of a crushed or scratched mineral is called its *streak.*

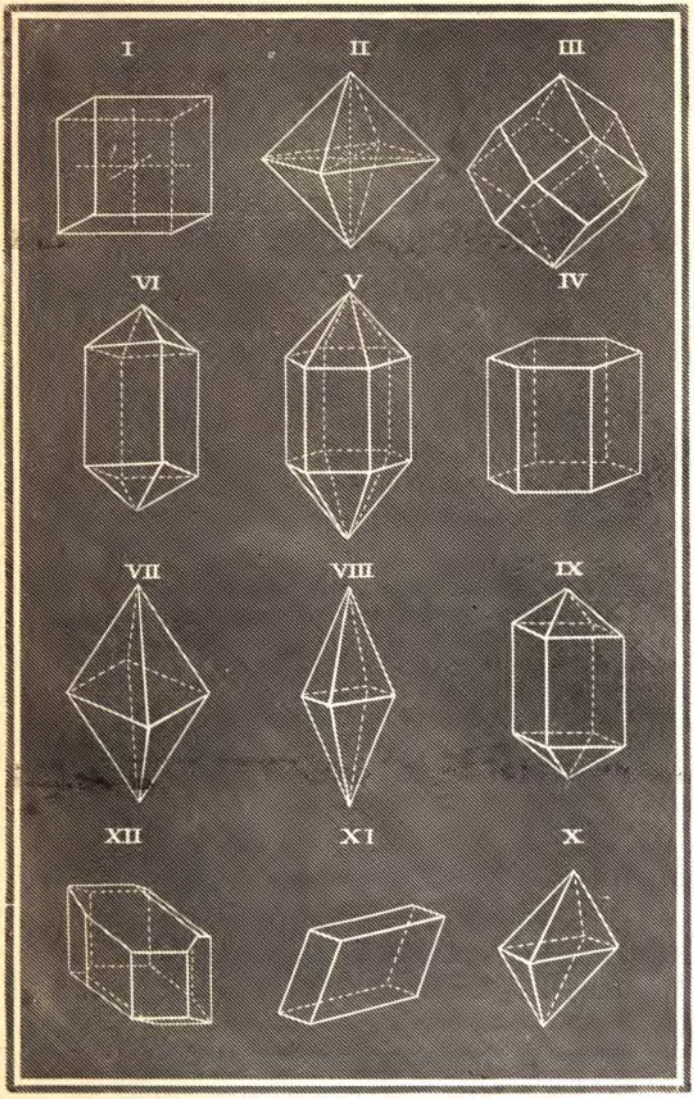


Fig. 37.

CHAPTER XXXIV.

STARCH, SUGAR, ETC.

ORGANIC chemistry treats of those compounds (composed principally of C, H, N, and O, but all containing C and H) which are formed chiefly by animals or plants in their processes of growth or *partial* decay. No line can be sharply drawn between organic compounds and inorganic. Many compounds which formerly were supposed to be produced only by the "vital force" of the plant or animal, have been formed recently in the laboratory.

As a rule, inorganic substances have few atoms in the molecule, while molecules of organic substances frequently contain a very large number of atoms. Often different organic substances contain the same elements in the same proportion. Thus the "empirical formula" (expressing only the proportions of the elements) of *cane suyar* is precisely the same as that of *gum arabic*, namely: $C_{12}H_{22}O_{11}$. This peculiar relation is called *isomerism*. Butyric acid and ethyl acetate, two well-known compounds, are isomeric, having the empirical formula: $C_4H_8O_2$, but the "rational formula" (which attempts to represent *in some way* the *arrangement* of the atoms in the molecule) of

Butyric acid=$H\overline{C_4H_7O_2}$. (REF. TABLE No. 2, Continued.)
Ethyl acetate=$\overline{C_2H_5}\,\overline{C_2H_3O_2}$. (REF. TABLE No. 2.)

Plants in general prepare food for animals from the mineral kingdom, and animals, after using it, return it to the mineral kingdom again. The organic by *complete* decay returns to the inorganic. The sun's light and heat (EXP. 58) is the motive power by which the plant is enabled to build up the organic out of the inorganic.

Starch ($C_6 H_{10} O_5$) is a substance found in all grains, in many roots, stems, and fruits. It is composed of grains, which the microscope reveals differing in size and shape in different plants. These grains swell up and burst on heating with water. Its use for food, in the laundry, etc., is well-known. Arrow-root and tapioca are varieties of starch from roots of tropical plants. Sago is starch from the pith of the sago-palm.

The test of starch is iodine, with which it forms a blue compound. (EXP. 84.)

EXP. 138.—Scrape some potato into cold water and squeeze through a linen cloth several times. The insoluble starch remains suspended in the filtrate, while the woody fiber (cellulose) remains upon the filter. After subsidence, pour off the water, and dry. This illustrates the method of obtaining starch from the potato.

When starch is heated to about 205°, it changes into an isomeric compound, **dextrin,** much used instead of gum arabic in making adhesive stamps. Dextrin is also formed, if starch is boiled with water slightly acidulated with sulphuric acid. If the boiling is continued longer, the dextrin is converted into starch-sugar ($C_6 H_{12} O_6$). Dextrin gives no blue color with iodine.

Gum arabic ($C_{12} H_{22} O_{11}$) exudes from a species of acacia. **Pectose** is a gummy substance found in many fruits and vegetables.

Cellulose ($C_{18} H_{30} O_{15}$), or woody fiber, is the frame-work of the cells of plants, and is found in every part, even in the pulpy fruits. **Linen,** made from the inner bark of flax, and **cotton**—the hollow white hairs around the seed of the cotton plant—are nearly pure cellulose (see cyclopædia). If paper is dipped in dilute sulphuric acid for a few moments, tough **parchment paper** results.

Gun-cotton is cellulose, in which part of the **H** has been replaced by the negative radical NO_2, by dipping in a mixture of HNO_3 and H_2SO_4. It is very explosive.

Gun-cotton, dissolved in ether (ethyl oxide) and alcohol (ethyl hydrate) forms **collodion,** much used by photographers.

Celluloid is made from gun-cotton and camphor, by submitting to great pressure. It can be colored in imitation of coral, made into collars and cuffs, and substituted, in general, for ivory. Its manufacture is comparatively a new industry.

Cane-Sugar, Sucrose, (C_{12} H_{22} O_{11}) may be obtained from the sugar-cane, beet-root, maple, and certain kinds of palm. In making it from the sugar-cane (1) the canes are crushed, (2) lime (Ca O) is added to the juice to neutralize any acid formed by fermentation, (3) the liquid is evaporated to jelly, (4) set aside to cool; (5) the sugar crystallizes, forming brown sugar, (6) it is put into perforated casks to drain. The drainings ("mother liquor") are molasses.

In the process of refining, brown sugar is (1) dissolved, (2) pumped to upper story of the high building, (3) filtered through twilled cotton bags, kept in bath of steam, (4) filtered through animal charcoal (EXP. 48), (5) evaporated in "vacuum pans" (kettles from which air is partially removed by pump, so that the syrup boils at a lower temperature and does not burn), and (6) set aside to crystallize. If in moulds, loaf-sugar results; if in centrifugal machines, granulated. The drainings are syrup or sugar-house molasses. (EXP. 98.)

Caramel is sugar carefully "burnt" so that it loses part but not all its water. It is used for coloring liquors, flavoring confectioneries, etc.

Cane-Sugar is not found in animal tissues or secretions, but is changed in the alimentary canal before absorption into grape sugar.

Grape-sugar ($\mathbf{C_6H_{12}O_6}$) **glucose,** (dextrose, starch-sugar, fruit-sugar) is found in honey, figs, grapes, and many kinds of fruit. It has much less sweetening power than cane-sugar.

EXP. 139.—To a solution of grape-sugar (made by boiling a few raisins in water and filtering) add three drops of copper sulphate (5 per cent. solution and slightly acidulated with acetic acid), then add strong solution of **K H O** (potash or **Na H O**, soda) till the light blue color of liquid becomes darker. Raise to the boiling point, but do not boil beyond a few seconds. A yellowish-red precipitate of cuprous oxide ($\mathbf{Cu_2O}$) falls. This is a delicate test for sugar in animal secretions (grape-sugar, or milk-sugar isomeric with cane). (See ADD. EXP.)

EXP. 140.—Divide a solution of cane-sugar into two parts; apply test as in EXP. 139, no cuprous oxide falls. Slightly acidulate the second portion with H_2SO_4, and boiling for ten minutes, the cane-sugar changes to grape-sugar. Apply test, and Cu_2O falls. Boil for some time a minute quantity of starch in dilute (2 per cent.) sulphuric acid. The starch changes to grape-sugar. Divide into two portions and test the first by iodine; no starch is found. Test the second, grape-sugar is found. Boil cellulose (woody fiber free from *pitch*) in dilute H_2SO_4 and grape-sugar is found in the solution.

The insoluble starch laid up in the seeds of plants is converted into (soluble) sugar by the action of a nitrogenous substance, called *diastase*, in the presence of *warmth* and *moisture*. The sugar is then absorbed by the growing plantlet, and is built into its structure as woody fiber, etc.

Fermentation is a species of decay. A necessary condition is the presence of some nitrogenous ("albuminous") substance, called a ferment, and the growth therein of a fungus plant called *yeast*. This plant is of a low order, and spreads by the rapid multiplication of cells throughout the whole fermenting substance, if it has the needed *warmth* (about 73°) and *moisture*. In the fermentation of substances containing grape-sugar (or cane-sugar which changes to grape-sugar), there are two stages:—

1. **The Alcoholic Fermentation,** in which the sugar breaks up into *alcohol* and *carbonic oxide*.

$$\underset{\text{grape-sugar.}}{C_6H_{12}O_6} = 2\,\underset{\text{alcohol.}}{C_2H_5HO} + 2\,\underset{\text{carbonic oxide.}}{CO_2}\uparrow$$

2. **The Acetic Fermentation,** in which, by exposure to the air, the alcohol is oxidized, forming *acetic acid* and *water*.

$$\underset{\text{ethyl hydrate.}}{C_2H_5HO} + \underset{\text{from the air.}}{O_2} = \underset{\text{acetic acid.}}{HC_2H_3O_2} + \underset{\text{water.}}{H_2O}$$

Beer, ale, etc., are made from **malt** (grain, that has germinated sufficiently to change nearly all the starch to sugar, and in which the fermentation has been checked by drying). The malt is crushed, and water, hops, and yeast added, when the alcoholic fermentation at once commences.

Wine is made by the fermentation of grape juice. If all the sugar is converted into alcohol and CO_2, **dry wine**, results. If the fermentation is checked (by boiling, or by an antiseptic, or both), when only part of the sugar is changed, **sweet wine** results. **Effervescing wine** is sealed in strong bottles while the alcoholic fermentation is going on.

When any fermented liquor is distilled, the **alcohol** (having a lower boiling point than water) passes over through the condenser (Fig. 16) first, together with certain flavoring substances and a certain part of the water. *Brandy* is made by distillation from wine, *rum* from fermented cane-juice, *whiskey* from fermented corn, rye, or potatoes, *gin* from fermented barley and rye, and afterwards distilled with juniper-berries (flavoring).

Alcohol (C_2H_5HO ethyl hydrate) is the *intoxicating principle* of all varieties of (unadulterated) "liquors." It is a colorless, volatile, inflammable, *poisonous* liquid. Its flame, as we have noticed, is hot and smokeless. It is a valuable *solvent*. Many substances, as resins, etc., insoluble in water, are soluble in alcohol. A solution of a substance (medicinal) in alcohol is a **tincture.** (See VOLATILE OILS.) Strong alcohol contains about 10 per cent. water, which cannot be removed by distillation. It may be removed by **Ca O**, or some other substance which has a great affinity for water, when anhydrous, or **absolute alcohol**, remains. Common alcohol belongs to marsh gas series.

EXP. 141.—Anhydrous (white) $CuSO_4$ (EXP. 34) is test for absolute alcohol. If water is present, the sulphate turns blue. Apply the test.

Common Ether, $(C_2H_5)_2O$, ethyl oxide, is made by distilling alcohol in presence of sulphuric acid. It is a very volatile, inflammable liquid. It produces great "cold" by its evaporation. If blown in a fine spray (from atomizer) upon some part of the body, the rapid cooling produces local anæsthesia (by "freezing" the spot.) It is inhaled as an **Anæsthetic**, and is a valuable *solvent*.

There is a large number of alcohols (hydrates of positive radicals) and corresponding ethers (oxides) arranged in series. **Methyl Alcohol**, (CH_3HO, wood spirit), is formed by the destructive distillation of wood, and resembles ethyl or common alcohol in many particulars.

Amyl Alcohol ($C_5H_{11}HO$, **fusel oil**), has a very fetid odor, and is much more poisonous than C_2H_5HO. It is formed in small quantities in the fermentation of potatoes and grain. Its boiling point is 137°, while that of ethyl alcohol is only 78°. The common alcohol is separated from it by **fractional distillation,** a valuable method of separating liquids whose boiling points differ materially.

The salts of the positive groupings of the ethers, or alcohols, are often termed "**compound ethers,**" (Ex.: ethyl nitrate, $C_2H_5NO_3$, etc.). Many of these "compound ethers" are sold as "essences," and they very closely imitate the true essences, Ethyl butyrate ($C_2H_5C_4H_7O_2$) is sold as "essence of pine-apple."

Chloroform ($CHCl_3$) is made by distilling alcohol with "chloride of lime." It is a colorless, volatile liquid, used as an **anæsthetic** and as a *solvent.*

Chloral (C_2HCl_3O), a colorless, oily liquid, is made by passing dry chlorine into alcohol. It combines with water of crystallization, forming a white crystalline substance, the so-called **chloral hydrate** ($C_2HCl_3OH_2O$). Chloral, when taken, reacts with the alkali of the blood, producing chloroform and *inducing sleep.* It is much used in medicine.

Acetic Acid ($HC_2H_3O_2$, the acid of vinegar), as we have seen, is produced by the fermentation, under the proper conditions, of substances containing sugar. It is produced *in the second stage,* by the oxidation of alcohol. Strong acetic acid crystallizes at 17° and is called glacial. The "mother" of vinegar is a fungus plant; it assists the fermentation by absorbing O from the air and giving it up to oxidize the alcohol. When the alcohol is all gone, however, it works mischief by oxidizing and destroying the vinegar itself (destructive fermentation). Sulphuric acid and pungent spices are often added to vinegar to increase its strength.

Carbolic acid (C_6H_5HO, phenyl hydrate), better classed with the alcohols (of phenyl series), is obtained from coal-tar. It is a very *poisonous* liquid (it may be obtained crystallized) and is a powerful *antiseptic* and *disinfectant.* Carbolic acid is sometimes confounded with creosote ($C_8H_{10}O_2$), the antiseptic principle of smoke (by which "bacon," etc., is "cured"); indeed, impure carbolic acid is commonly called creosote.

Benzol (C_6H_5H, phenyl hydride—see ILLUMINATING GAS) is a very volatile, inflammable liquid, is a valuable *solvent*, and is used to remove grease spots from silk and woolen articles. From it, by the action of nitric acid, **nitrobenzol** ($C_6H_5NO_2$), an oily liquid is prepared. By the action of reducing agents upon nitrobenzol the celebrated **aniline** (C_6H_7N), the source of the "coal-tar" dyes, is prepared (see DYEING).

(For tar, coal-tar, naptha, kerosene oil, dead-oil, petroleum, bitumen, etc., see cyclopædia.)

There are three great classes of (*organic*) foods:—

1. **Starch,** or sugar and allied bodies.
2. **Oleaginous** substances. (See Chap. XXXVII.)
3. **Albuminous** substances ("nutritious matter," nitrogenous matter.)

Albumen (formula very complex, C.. H.. N.. S.. O..) is found nearly pure in white of eggs. Albuminous matter possesses the power of (1) becoming a ferment, (2) of coagulation, and (3) of putrefaction. **Casein** is found in milk, and is coagulated by rennet (acid); **gluten,** in flour, meal, etc.; **fibrin,** in blood, and another variety of fibrin in muscular tissue. (See ADD. EXP.)

EXP. 142.—Soak a small bone over night in **H Cl** (30 per cent.). The mineral matters are dissolved, and the soft animal matter left. Wash thoroughly in water and leave in water over night again. Boil the animal matter for some time in a small quantity of water and set aside to cool. A gelatinous substance remains.

Gelatin (formula complex; a nitrogenous substance not belonging to albuminous matter *proper*) is formed by the action of hot water upon animal membranes, tendons, and bones. **Glue** is very impure gelatin. **Isinglass** is very pure gelatin from the air-bladders of fish. (The mineral, mica, used in the doors and sides of parlor stoves, is often improperly called *isinglass*).

Flour consists of gluten, starch, and a little dextrin and sugar. (The oily and mineral substances are contained chiefly in the bran of the grain, hence "coarse food," as corn meal, graham flour, oatmeal, cracked wheat, etc., are very necessary for the proper development of bone and sinew.) In bread-making the flour, mixed with milk (or water), containing yeast, is set in a warm place, and immediately fermenta-

tion begins. The CO_2 set free is held by the gluten, causing the dough "to rise." This is kneaded, to distribute evenly the fermentation and to break up the large bubbles of CO_2. In baking, the CO_2 and alcohol escape. If the oven is too hot, a crust forms too quickly, prevents the escape of the CO_2, and large cavities are formed. If the fire is not hot enough, the CO_2 escapes before the cells are sufficiently hardened, and the bread falls. Sour bread is formed when before (or while) baking the second stage (acetic) of fermentation is reached. **Saleratus** ($HKCO_3$), or **Soda** ($HNaCO_3$), is added to prevent this by neutralizing any acid that may form. In raising biscuit, "soda" and "cream of tartar" ($HKC_4H_4O_6$) are used to furnish the CO_2, while the salt that remains is a harmless one. Common **Baking Powder** is merely "cream of tartar" and "soda," but it is often adulterated with alum, to make inferior flour look white. Bread containing alum is highly injurious, producing chronic constipation. (See ADD. EXP.) **"Yeast Cakes"** are made by exposing *moistened* corn meal, containing a ferment, to *moderate temperature* till the gluten is in the midst of the alcohol fermentation. The fermentation is then checked by drying. The yeast plant (fungus) throughout the cake may be likened to so much dry *seed*, which needs only to be sown in the right soil (in the dough).

[The chemical changes in the body (Physiological Chemistry) are too difficult for insertion in a primary work.]

CHAPTER XXXV.

VEGETABLE ACIDS and BASES (ALKALOIDS).

Compounds of **oxalic acid** ($H_2\overline{C_2O_4}\,2H_2O$), especially $K_2C_2O_4$, and CaC_2O_4 are found in *rhubarb, sorrel*, etc. (also a very little of the free acid.) The acid is a powerful *poison*. It is sold as "salts of lemon" (a *dangerous name*), to remove ink stains.

$$\underset{\text{iron tannate (ink)}}{Fe_3\,2\overline{C_{27}H_{19}O_{17}}} + \underset{\text{oxalic acid}}{3H_2C_2O_4} = \underset{\text{tannic acid}}{2H_3\overline{C_{27}H_{19}O_{17}}} + \underset{\text{iron oxalate (soluble)}}{3FeC_2O_4}$$

The iron oxalate and tannic acid formed should be immediately washed out of the cloth, else the cloth will be corroded. Oxalic acid

readily dissolves metallic oxides, forming oxalates, and hence is used to clean brass and copper, and to remove spots of iron-rust. It is made on a large scale by heating sawdust and caustic potash (**K H O**).

Salts of **tartaric acid** ($H_2\overline{C_4H_4O_6}$), also minute quantities of the free acid, exist in many fruits, and especially in the *grape* (as acid potassium tartrate, $HKC_4H_4O_6$). It settles during fermentation, forming a crust ("argol," "bitartrate of potash") which, when purified, is **cream of tartar** ($HKC_4H_4O_6$). **Tartar emetic** is a double *salt: potassium* antimonyl tartrate ($K\overline{SbO}\,\overline{C_4H_4O_6}$). **Rochelle salt** is ($KNaC_4H_4O_6$)

Citric acid ($H_3\overline{C_6H_5O_7}H_2O$) is the acid of the lemon, lime, etc. Its salts are also present.

Malic acid ($H_3\overline{C_4H_3O_5}$) occurs (together with potassium malate) in most *unripe* fruits, especially unripe apples.

Tannic acid ($H_3C_{27}H_{19}O_{17}$—tribasic?), or **tannin,** is found in the leaf and bark of most trees and of many shrubs (oak especially, in nut galls, hemlock, etc.), together with a little gallic acid ($H_3C_7H_3O_5$, H_2O).

EXP. 143.—To a solution of tannic acid add a solution of gelatin; a yellowish-white precipitate of gelatin tannate falls.

In the process of **tanning,** the tannic acid unites with the gelatin of the hide, forming a tough compound **(leather).**

EXP. 144.—To a solution of tannic acid add copperas solution. Ink is formed, becoming darker by exposure to the air. (*Ous* salts of **Fe** have a tendency to oxidize and form peculiar and, as a rule, less soluble "oxy-salts.")

$$\underset{\text{copperas}}{3FeSO_4} + \underset{\text{tannic acid}}{2H_3C_{27}H_{19}O_{17}} = \underset{\text{INK}}{Fe_32C_{27}H_{19}O_{17}} + \underset{\text{corrodes pens.}}{3H_2SO_4}$$

Leather is blackened by washing one side with solution of iron sulphate, thus covering it with ink. Creosote or corrosive sublimate ($HgCl_2$), *antiseptics,* are used to keep ink from moulding.

The **alkaloids** are organic *bases* (see comments EXP. 3 and 4) and they form salts on the *ammonia type.* Many of them have a bitter taste, are *powerful poisons,* and valuable medicines (see ANTIDOTES). The liquid alkaloids

(few) contain C, H and N, while the solid (nearly all) contain C, H, N, and O. Their salts occur in the plants from which they are obtained.

NOTE.—The theory of **types** has done much to advance the science of chemistry. The pupil, however, must distinguish between *theory* and *fact*. The formation of compounds on the water type is strictly represented thus:—

$$\left.\begin{matrix}\mathbf{H}\\\mathbf{H}\end{matrix}\right|\mathbf{O} \;=\; \text{water} \qquad \left.\begin{matrix}\mathbf{NO_2}\\\mathbf{H}\end{matrix}\right|\mathbf{O} \;=\; \text{nitric acid}$$

in which the negative radical, nitryl ($\mathbf{NO_2}$), replaces an atom of **H** in the molecule of water. So:—

$$\left.\begin{matrix}\mathbf{H_2}\\\mathbf{H_2}\end{matrix}\right|\mathbf{O_2} \;=\; \text{two molecules of water,} \qquad \left.\begin{matrix}\mathbf{SO_2}\\\mathbf{H_2}\end{matrix}\right|\mathbf{O_2} \;=\; \text{sulphuric acid}$$

in which two atoms of **H** in the water have been replaced by the negative radical sulphuryl, $\mathbf{SO_2}$. The reaction in EXP. 15, written strictly to represent the water type, becomes:—

$$\left.\begin{matrix}\mathbf{Na}\\\mathbf{H}\end{matrix}\right|\mathbf{O} + \left.\begin{matrix}\mathbf{C_2H_3O}\\\mathbf{H}\end{matrix}\right|\mathbf{O} = \left.\begin{matrix}\mathbf{C_2H_3O}\\\mathbf{Na}\end{matrix}\right|\mathbf{O} + \left.\begin{matrix}\mathbf{H}\\\mathbf{H}\end{matrix}\right|\mathbf{O}$$

It is easily seen how the negative radical, usually considered by chemists as the *replaceable* and *replacing* quantity in reactions, is obtained from the negative "grouping," viz.: by subtracting one atom of **O** from monad groupings, two from dyad groupings, etc. Negative radicals usually take the termination, *yl*. Again, binary acids and salts can not *in any strict sense* be referred to the water type as in this book, but must be referred to the hydrochloric acid type. The formation of compounds on the **ammonia type** is shown in the following formulas, the *connecting element* being the triad, **nitrogen.** The examples given are artificial compounds (alkaloids):—

$$\left.\begin{matrix}\mathbf{H}\\\mathbf{H}\\\mathbf{H}\end{matrix}\right|\mathbf{N} \;=\; \text{ammonia} \qquad \left.\begin{matrix}\mathbf{C_6H_5}\\\mathbf{H}\\\mathbf{H}\end{matrix}\right|\mathbf{N}\ \text{phenyl-amine (aniline)} \qquad \left.\begin{matrix}\mathbf{C_2H_5}\\\mathbf{H}\\\mathbf{H}\end{matrix}\right|\mathbf{N}\ \text{ethylamine}$$

$$\left.\begin{matrix}\mathbf{C_2H_5}\\\mathbf{C_2H_5}\\\mathbf{H}\end{matrix}\right|\mathbf{N}\ \text{diethyl-amine} \qquad \left.\begin{matrix}\mathbf{C_2H_5}\\\mathbf{C_2H_5}\\\mathbf{C_2H_5}\end{matrix}\right|\mathbf{N}\ \text{triethyl-amine.}$$

If the **H** of ammonia (one or more atoms) is replaced by a positive radical, an *amine* results; if by a negative radical, an *amide*; if a positive and a negative both take part in the replacement, an *aikalamide*—all giving rise to very hard names. The **ammonia type** should be

considered only in this respect by beginners. Ammonia forms salts with the acids, *without replacing the hydrogen* of the acid. The alkaloids do the same thing. Ex.: $H_3N + HCl = H_4NCl$. Ammonium chloride may be written, $\overline{H_3N\,HCl}$; chloride of ammonia, so $\overline{C_6H_7N,\ HCl}$ = chloride of **aniline**, and $\overline{C_{17}H_{19}NO_3\,HCl}$, $3H_2O$ = chloride (or "hydrochlorate") of morphia (with water of crystallization). (For fuller account of each alkaloid, see cyclopædia.)

Morphia ($C_{17}H_{19}NO_3$, H_2O), or **morphine**, is the principal alkaloid in opium, the dried juice of the poppy. In small doses it acts as a *sedative;* in large doses, as a *narcotic poison.* It is combined with meconic acid in the plant as meconate of morphia. A salt of morphia, (sulphate or chloride, usually) is sold at the drug stores as "morphia," and the same is true of many other alkaloids. **Laudanum** is tincture of opium; **paregoric**, a camphorated tincture, flavored with aromatics. Many patent concoctions for "soothing" children contain opium, and are very pernicious.

Quinia, or **quinine** ($C_{20}H_{24}N_2O_2\,3H_2O$), is obtained from the bark of the cinchona, a tree found native in Peru. It is largely used in medicine, especially in **fevers.** It has a bitter taste.

Aconitia, or **aconite** ($C_{54}H_{46}NO_2$), is obtained from aconite leaves and root. It is used in **fevers** to cause perspiration (sudorific). It is one of the most violent poisons known.

Strychnia, or **strychnine** ($C_{21}H_{22}N_2O_2$) is the alkaloid in nux vomica (seeds) and the St. Ignatius bean. It also is one of the most poisonous of the alkaloids. It is largely used in medicine as a nervous **tonic.** It is intensely *bitter.*

Atropia ($C_{17}H_{23}NO_3$) exists in belladonna, or Deadly Nightshade, as malate of atropia.

Nicotia, or **nicotine** ($C_{10}H_{14}N_2$), is the volatile *liquid* alkaloid of the tobacco plant. It is intensely poisonous, but unfortunately, being so volatile, its smoke does not kill. The human system at length becomes tolerant of the presence of the poison, even in the stomach.

As a rule, it stupifies and clouds the intellect, especially of persons not full grown. Those boys who are great smokers rarely take a high standing in their classes.

The alkaloids are very numerous, as are also the vegetable acids. For tests see larger text-books.

CHAPTER XXXVI.

DYEING.

EXP. 145.—Dissolve a little aniline blue ($C_{20}H_{16}(C_6H_5)_3N_3$) in alcohol, and dip clean, white silk thread into it. Expose the thread to the air, the alcohol evaporates and leaves the blue color adherent to every fiber of the silk.

Aniline ($C_6H_5H_2N$) is a volatile, oily liquid; colorless, when pure, but by oxidation, *action of chemical agents*, etc., aniline black, red, (magenta), orange, yellow, green, blue, and violet (mauve) are produced. The *reactions* in the formation of the wonderful "aniline dyes" are by far too complex for introduction here.

EXP. 146.—Upon fine zinc filings in a beaker place a minute quantity of blue indigo, add a moderately strong solution of potassium hydrate (potash) and heat.

$$\text{(a)—}Zn + 2KHO = KZnO_2 + \underset{\text{nascent}}{H_2}.$$

$$\text{(b)—}\underset{\text{reducing agent}}{H_2} + \underset{\text{blue indigo}}{C_{16}H_{10}N_2O_2} = \underset{\text{white indigo}}{C_{16}H_{12}N_2O_2}$$

Dip a piece of clean, white woolen (or cotton) cloth in the solution of white indigo and expose to the air, blue indigo is formed in its fibers by oxidation and adheres, that is, is a "*fast*" color (does not wash out in warm soap-suds).

$$\underset{\text{white indigo}}{C_{16}H_{12}N_2O_2} + O = \underset{\text{blue indigo}}{C_{16}H_{10}N_2O_2} + \underset{\text{evaporates}}{H_2O}$$

EXP. 147.—Divide a dilute (1 per cent.) solution of **picric acid** ($C_6H_3N_3O_{10}$) into two portions. Into one dip a piece of woolen yarn, into the other dip cotton yarn. Remove each and wash. The first is dyed a brilliant yellow, the second is not colored.

Substances that dye directly are called *substantive colors*. Coloring substances may form colored compounds with the fibers of the cloth, or (usually) may merely adhere to the fibers. Cotton and linen often require different treatment from wool or silk to produce the same color, and, in general, are dyed with more difficulty.

EXP. 148.—Divide a solution of *alum* into two parts. To the first add H_4NHO, a flocculent precipitate of aluminum hydrate ($Al_2 6HO$) falls. To the second add a few drops of solution of *cochineal (carmine* ink), and then H_4NHO. $Al_2 6HO$ is precipitated as before, and *slowly* settles, *carrying all the coloring matter down with it*, forming a "*lake.*"

Some other metallic hydrates (or oxides), especially of tin and of iron, have the same great affinity for organic coloring matter. The compounds they form with coloring matters are called *lakes.* The hydrates also have "great affinity for" (adherence to) the fibers of cloth. Every one knows, that, though "dirt" can be readily washed from a white apron, iron rust is removed with great difficulty (only by chemical agents—see OXALIC ACID). Hydrates (or salts, from which the hydrates may be produced), that have a great affinity for coloring matter and also for the fiber of cloth, are called *mordants,* and a color that will not dye directly, but needs a mordant, is called an *adjective color.*

Coloring by means of **mordants** is the usual method. The most common mordants are copperas, tin salts, and alum. The cloth is first dipped into a solution of the mordant and then into the dye. Different mordants produce different colors, when used with the same dye. The mordants may be applied by means of stamps (or rollers) and any pattern (as for calico) brought out in the various colors.

EXP. 149.—Boil a piece of $FeSO_4$ in nitric acid (90 per cent.), till red flumes cease to appear; dilute and filter. Preserve filtrate ($Fe_2 3SO_4$, "persulphate of iron"). Dip *clean* silk into this ferric sulphate (mordant) and leave for a few minutes. Drain, and immerse in solution of potassium ferro-cyanide (dye). It is colored a deep blue (Prussian blue).

$$\underset{\text{mordant}}{2Fe_2 3SO_4} + \underset{\text{dye}}{3K_4\overline{Fe(CN)}_6} = 6K_2SO_4 + \underset{\substack{\text{ferric ferro cyanide}\\ \text{Prussian blue}}}{(Fe_2)_2 3\overline{Fe(CN)}_6}$$

The reactions of the organic dyes with their mordants are too complex to be written out. Indeed, many of them are unknown. The most common coloring substances are *madder* (coloring principle alizarin, now made artificially from coal-tar), cochineal (dried insects from cactus of Central America, coloring principle, *carmine*), logwood, indigo, litmus, etc. (See DYEING, in cyclopædia).

CHAPTER XXXVII.

OILS, FATS, RESINS, ETC.

There are two great classes of oils: **Fixed** and **Volatile** (or **Essential**). Fixed oils cannot be distilled without decomposition into various hydrocarbons. Volatile oils can be readily distilled.

Fixed oils are salts (using the term in a wide sense). Hard fat is principally glyceryl stearate ("stearin"), soft fat, glyceryl palmitate ("palmitin"), and liquid fat, glyceryl oleate ("olein"). Fixed oils, when boiled with an alkali (K, Na, etc, hydrate), react with the alkali to form a **"soap,"** and **"glycerine."** (TABLE NO. 2).

EXP. 150.—Mix a strong solution of caustic potash (**KHO**) with olive oil and boil for about twenty minutes.

$$\underset{\substack{\text{potassium}\\\text{hydrate}\\\text{("lye")}}}{3\,KHO} + \underset{\substack{\text{glyceryl oleate}\\\text{(olive oil)}}}{C_3H_5\,3\,C_{18}H_{33}O_2} = \underset{\substack{\text{potassium oleate}\\\text{(\textit{soft} soap, because it is a}\\\textit{deliquescent} \text{ salt)}}}{3\,KC_{18}H_{33}O_2} + \underset{\substack{\text{glyceryl hydrate}\\\text{(glycerine)}}}{C_3H_5\,3\,HO}$$

Set aside to cool, the soap and glycerine separate.

Olive oil contains some glyceryl palmitate, so that the soap is partly potassium palmitate. If tallow be taken in place of olive oil, the soap is principally potassium stearate. Inspection of the reaction reveals the whole story of soap-making. If "caustic soda" is taken with tallow, the reaction becomes

$$\underset{\text{caustic soda}}{3\,NaHO} + \underset{\text{glyceryl stearate}}{C_3H_5\,3\,C_{18}H_{35}O_2} = \underset{\substack{\textit{hard} \text{ soap}\\\text{(not deliquescent)}}}{3\,NaC_{18}H_{35}O_2} + \underset{\text{glycerine}}{C_3H_5\,3\,HO}$$

Potassium forms a soft soap and sodium a hard soap. Ca forms an insoluble "lime soap." Mg also forms an insol-

uble soap. Insoluble soaps are sometimes used in medicine and in the arts. Solutions of soluble soaps (K and Na) are good *solvents* of the cuticle and of many forms of "dirt," and hence are valuable cleansing agents. They must be used, however, with soft water. If soft soap (for instance) is put into hard water (*i. e.*, containing $CaSO_4$, or other soluble sulphate), the soap is destroyed, and an insoluble "lime soap" formed by the following reaction:—

$$\underset{\text{cause of hardness}}{CaSO_4} + 2\underset{\text{soft soap}}{KC_{18}H_{33}O_2} = K_2SO_4 + \underset{\text{insoluble lime soap}}{Ca\,2\,C_{18}H_{33}O_2}$$

A similar reaction takes place, if the water is only of temporary hardness (see EXP. 33). Water of temporary hardness, as we have seen, is softened *by boiling*. Water of permanent hardness may be softened (for washing purposes) by adding borax ($Na_2B_4O_7$), or washing soda ($Na_2CO_3, 10H_2O$). If the last,

$$\underset{\text{cause of hardness}}{CaSO_4} + Na_2CO_3 = \underset{\substack{\text{(remaining in solution but not affecting the soap)}}}{Na_2SO_4} + \underset{\text{precipitate}}{CaCO_3}$$

In making **"lye"** from wood ashes, the ashes are leached in a large tub containing "lime" ($Ca\,2\,HO$) at the bottom. The K_2CO_3 of the ashes is carried by the hot water down through lime, and the reaction is:—

$$Ca\,2\,HO + K_2CO_3 = \underset{\text{"lye"}}{2\,KHO} + CaCO_3$$

If no lime is used of course the lye is potassium carbonate (impure solution), and in making soap from K_2CO_3 we have (if olive oil is used)

$$3\,K_2CO_3 + 3\,H_2O + 2\,C_3H_5\,3\,C_{18}H_{33}O_2 =$$
$$\underset{\text{soap}}{6\,K\,C_{18}H_{33}O_2} + 2\,C_3H_5\,3\,HO + 3\,CO_2$$

Soap usually contains an excess of the alkali. Home-made soap contains both alkali and glycerine and is very variable in its composition, containing several fat acids united to the alkali. Soap is insoluble in salt-water and hence separates if salt be added to the "suds."

"**Stearin**" **candles** are made (chiefly) of stearic acid by decomposing the tallow by superheated (285°) steam.

$$\underset{\text{steam}}{3\,H_2O} + \underset{\text{tallow}}{C_3H_5\,3\,C_{18}H_{35}O_2} = \underset{\substack{\text{stearic acid}\\(\text{stearin candles})}}{3\,H\,C_{18}H_{35}O_2} + \underset{\text{glycerine}}{C_3H_5\,3\,HO}$$

There are two great classes of fixed oils, **drying** oils and **non-drying** oils. A drying oil (as linseed oil, *i. e.*, flax-seed oil), when exposed to the air, oxidizes to a hard resinous substance. A non-drying oil does not oxidize to a resinous body when exposed to the air, but instead suffers a fermentation that sets the acid of the oil free, that is, the oil becomes "*rancid.*" For instance, the purest olive oil is not entirely free from nitrogenous material, and fungus germs, creeping in, cause the following reaction :—

$$\underset{\text{olive oil}}{C_3H_5\,3\,C_{18}H_{33}O_2} + \underset{\substack{\text{moisture}\\\text{from air}}}{3\,H_2O} = \underset{\text{oleic acid}}{3\,H\,C_{18}H_{33}O_2} + \underset{\text{glycerine}}{C_3H_5\,3\,HO}$$

As we have seen, **glycerine** ($C_3H_5\,3\,H\,O$) is a "*by-product*" in the manufacture of soap. **Glycerine** is classed by chemists as an alcohol. It is a viscid, sweet liquid, a good solvent and a valuable *antiseptic.* It is useful in dressing wounds, because it is not volatile, but protects from the air and keeps the part moist. Glycerine, treated with nitric and sulphuric acids, becomes the fearful explosive *nitro-glycerine* ($C_3H_5\,3\,N\,O_3$, glyceryl nitrate).

Volatile oils (or **Essential oils**) are of vegetable origin. They exist in the petals of flowers, in leaves (of mint), in seeds (of carraway), in rind of fruit (of orange, lemon) and in the root (of sassafras). They are usually obtained by distilling with water (passing steam over), from the part of the plant containing them. They do not make soaps. Their "solution" in alcohol is called an **essence.** Adulteration with a fixed oil is easily discovered by evaporating on white paper and noticing that a *grease spot* is left.

Oil of Turpentine ($C_{10}H_{16}$ "spirits of turpentine") is obtained from the "pitch" of pines by distillation." It is an excellent *solvent,*

dissolving the resins to form *varnishes*. A large class of volatile oils are pure hydro-carbons, many having the same empirical formula with oil of turpentine, though widely different in properties.

Of a second class Camphor (C_{10} H_{16} **O**) is a type, as oil of bitter almonds, cinnamon, spearmint, etc. These all contain **O**.

A third class of "*strong smelling*" volatile oils contain **S**. Ex: Oil of mustard, horse-radish, onion, etc.

A **resin** is an essential oil oxidized. ("**Rosin**" is the resin of "turpentine"). A **balsam** is an oleo-resin, *i. e.*, a resin dissolved in a volatile oil, or a volatile oil partially oxidized. If a balsam is distilled, the essential oil passes over, leaving the resin behind. **Shellac** is a resin obtained from lac, the juice of an East India tree. **Amber** is a fossil resin.

Gum resins are milky exudations from many plants, which afterward solidify in the air. **Gutta-percha** is obtained from the juice of an East India tree, as is also **gum-benzoin**, the chief source of benzoic acid (**H** C_7 H_5 O_2) **India-rubber** (caoutchouc) is the solidified juice of certain tropical trees. Vulcanized rubber is made by heating the rubber with sulphur (Goodyear's patent).

CHAPTER XXXVIII.

ANTIDOTES.

When a person is taken suddenly and violently ill after eating something, poisoning may be suspected.

A **poison** is a substance, which, if introduced into the animal system, may produce morbid or deadly effects. We give antidotes, either (1) *to get rid of the poison at once* (by means of an emetic, or cathartic—a mechanical anti dote), or (2) *to hinder its absorption* (as when we give a chemical antidote to form an insoluble compound with the poison: see EXP. 11), or (3) *to counteract its effect* (as when we give stimulants for the poison of serpent bites, for narcotic poisons, etc.).

EXP. 151.—Shake up thoroughly the white of an egg in a bottle half filled with water and filter. The filtrate is a solution of albumen. Arrange test tubes containing *very slightly acid* solution of soluble salts of **Hg** (corrosive sublimate), **Cu, Zn, Sn, Fe** (copperas), **Ag** (nitrate), **Pb** and **As** respectively. Into each let fall two or three drops of albumen solution. Insoluble compounds (of albumen and the metal, formula too complex to be written) are precipitated.

Albumen (**milk,** flour and water, and especially **raw eggs**) is an excellent chemical antidote for metallic salts. As precipitates are not absolutely insoluble *in the stomach,* they should be immediately removed by an **emetic.**

The best emetic is the common one, "mustard" (a teaspoonful in a cup of—preferably warm—water). Whenever poisons are to be removed by an emetic, warm water should be freely drank to rinse out the stomach thoroughly. **Oils** (fats, butter, and lard) and mucilaginous drinks (as flax-seed tea) **are always beneficial,** both immediately and for treatment afterward. In general, whatever would be good treatment for a *burned, bruised, or injured skin,* is good treatment *for the mucous membrane of the alimentary canal,* burned and irritated by some poison.

If silver nitrate or corrosive sublimate are quite *strong,* the antidote must be given *within a few seconds,* or the poison will have done its worst, and recovery, if it takes place at all, must depend upon after treatment. A rather large dose of a mild cathartic (as castor oil) is much to be preferred to the emetic whenever *strong* solution of either sublimate or nitrate has been taken. The best antidote for silver nitrate is salt and water, as we have inferred from EXP. 5.

If the other metallic salts (except, see cyanides below) have been swallowed, especially in the solid state (powder), the antidote may be given later (from ten to twenty minutes) with hope of its doing good. But *the danger rapidly increases with the lapse of time.*

Most salts of **Zn** and **Sb** (also **Cu S** O_4) are fortunately emetics themselves, but if vomiting does not occur, prompt action must be resorted to. The best antidote for zinc, copper, or iron sulphate is **sodium carbonate,** "washing soda" (followed by emetic).

$$\mathbf{Zn\,SO_4} + \mathbf{Na_2\,CO_3} = \mathbf{Na_2\,SO_4} + \underset{\text{insoluble}}{\mathbf{Zn\,CO_3}}$$

The best antidote for arsenic (or **Sb**) is fresh, moist ferric hydrate, $\mathbf{Fe_2\,6\,HO}$. It is best precipitated when needed (by mixing **H Cl** solution of ferric chloride and sodium carbonate). An insoluble ferric arsenate ($\mathbf{Fe_2\,2\,As\,O_4}$) is formed in the stomach. Chalk and oil mixed may be given to envelop the particles of **As** mechanically, but the thing to be depended upon ordinarily is the *emetic*.

"Carefully prepared iron filings (Exp. 125) is a good antidote for copper compounds (with emetic)."—*Attfield.* A careful dose of potassium ferrocyanide, is also a good antidote, as $\mathbf{Cu_2\,Fe\,(CN)_6}$ is insoluble.

Magnesium sulphate (Epsom salt) [Exp. 11] is the best antidote for lead and barium compounds (with emetic).

Ammonium carbonate (small dose of 5 per cent. solution, as itself is poisonous) is the best antidote for tin compounds (with emetic).

Example:

$$\mathbf{Sn\,Cl_2} + \mathbf{(H_4N)_2\,CO_3} + \mathbf{H_2O} = \mathbf{2\,H_4\,N\,Cl} + \underset{\text{precipitate}}{\mathbf{Sn\,2\,HO}} + \mathbf{C\,O_2}\uparrow$$

The antidote for **acids** (sulphuric, nitric, hydrochloric, etc.) is **magnesium carbonate** (see Reaction, class 4), chalk, lime-water or soapsuds. The antidote must be given within *a few seconds* if the acids are strong.

For oxalic acid, lime-water (Exp. 14) or chalk is the best antidote. Prussic acid (**K CN**) and other cyanides require stimulants, as cold douche to the spine, *dilute* ammonia water inhaled and ammonium carbonate given in *small doses* (see snake poison below). If prussic acid is strong there is no antidote. **Give no emetics with acids** (unless acid is *very dilute*), but administer oil freely (olive).

The antidote for **alkalies** (caustic potash ("lye"), caustic soda, etc.) is a dilute acid, preferably the most common one **vinegar** (acetic).

$$\mathbf{K\,HO} + \mathbf{HC_2H_3O_2} = \underset{\substack{\text{soluble but}\\ \text{harmless salt}}}{\mathbf{K\,C_2H_3O_2}} + \mathbf{H_2O}$$

Or tartaric acid, "cream of tartar," citric acid (lemon juice) etc. (If these are not at hand and the mineral acids are given, the acid must be very dilute and given sparingly. *An overdose would be substituting one poison for another*).

If the caustic alkalies are strong, the antidote must follow *in a few seconds*, or it will be of no avail. **Give no emetic with alkalies,** (unless they are *very dilute*, and no other remedies as the above, or *oil*, can be had).

For **narcotic poisons** (as opium, morphine, cholera medicines, "soothing syrups"), and the **alkaloids** in general, the **emetic is to be relied upon** chiefly, though *tannic acid* (strong tea or coffee) may be given, as it forms an insoluble compound with many alkaloids.

The narcotic poisons require in addition to the emetic, *stimulants* (strong coffee, brandy, ammonium carbonate—avoid overdose of latter, see below) and vigorous efforts to *keep the patient awake*. *Aconite* calls for *stimulants*. *Strychnine* requires above all the *emetic*, also the inhalation of chloroform or ether to check spasms. Patient must be kept as *quiet as possible*.

The **emetic** should be promptly given in case of poisoning by **unhealthy fish or meat. Oils** should follow (and paregoric in severe cases).

Phosphorus poisoning requires the **emetic** and mucilaginous drinks with magnesium hydrate, followed by large doses of the **cathartic** (purgative) castor oil.

It is not generally known that **carbolic acid** is a more dangerous poison than strychnine. Strichnine kills "deliberately" and with a smaller dose, but carbolic acid does its work *quick*. Strychnine gives time (10 to 30 minutes) to hunt up antidotes, or call a physician; but if a teaspoonful of strong carbolic acid is taken, usually no remedy will save life after *thirty seconds* have elapsed. As it is frequently used in sick rooms for bathing purposes (diluted), its well known odor is no protection in such cases. **Olive oil** (butter, lard, etc.) freely given, followed by **castor oil** (cathartic) is its best antidote. **Give no emetic.**

For the bite of **poisonous serpents** (poison, a powerful sedative), stimulants, as alcoholic liquors, but best of all, ammonium carbonate (a teaspoonful of 10 per cent. solution, which may be carried in small vial, *tightly corked*, in the vest pocket) should be taken *within a few seconds*. The dose of ammonium carbonate should be

repeated twice at intervals of ten minutes. If possible, the wound should be immediately cauterized (by nitric acid, caustic potash, etc.), or a ligature put about the limb above, and the poison sucked out from the wound (the poison is harmless in the stomach).

The pupil will notice, that in most cases of poisoning, the **emetic** is given. He should charge his memory with the few exceptions [moderately strong *acids, alkalies* (also silver nitrate, corrosive sublimate) and *carbolic acid*], and give emetics in all other cases. A physician should be called in all cases of serious poisoning to direct the after-treatment.

Poisons should never be left within the reach of children. They should be kept by themselves, apart from non-poisonous medicines. They should be kept *plainly labeled* as poisons, and any substance in an unlabeled bottle should be promptly destroyed. Whenever a poison is bought, its antidote should be bought, placed beside it and plainly labeled. After this is done, it should be remembered that "an ounce of prevention is worth a hundred pounds of cure."

MISCELLANEOUS QUESTIONS.

1. Tell what you know of SO_2 (3 lines).
2. Tell what you know of H_2S.
3. What is glass? How annealed?
4. How might you tell whether, or not, a white powder was As_2O_3?
5. Give Marsh's test for "arsenic." How told from antimony?
6. What is an alloy? amalgam? metal?
7. What three methods of "mining for gold?" and tell much more about each than you find in this Primer (20 lines).
8. For what is platinum used?
9. What would you do, if you had taken by mistake nitrate of **Ag**?
10. How would you test for corrosive sublimate ($HgCl_2$)?
11. Why can some metals be cast, while others can not?
12. What is "white lead," and how made?
13. What is the antidote for lead acetate?
14. Give Bessemer's process for making steel.
15. What is "galvanized iron?" "tin ware?"
16. What is fusible metal?
17. Difference between water-slacked and air-slacked lime?
18. Give reaction in making soft soap (use TABLE).
19. How is brown sugar refined?
20. Reactions in alcoholic and acetic fermentations ($C_6H_{12}O_6$ sugar).
21. Why is soap wasted when hard water is used in washing?
22. What is rosin? a resin? balsam? tincture?
23. What would you do, if one had taken an overdose of morphine?
24. In what cases of poisoning should no emetic be given?
25. What makes the bread "rise?" Explain fully.

APPENDIX.

ADDITIONAL EXPERIMENTS.

EXP. 1.—Repeat EXP. 30 with a test tube of the right size and the **H** flame "sings." It sets the column of air in vibration within the test tube.

EXP. 2.—Ignite a small jet of **H** by holding in it platinum sponge [previously heated to expel absorbed gases which (especially ammonia) hinder the action].

EXP. 3.—Place a sounding tuning-fork in a jar of **H**; the tone is raised to a shrill pitch.

EXP. 4.—Burn a minute jet of **O** (driven by reservoir (1) from holder (3) as in **frontispiece**) in a jar of **H**, quickly igniting the jet by passing through burning **H** at the mouth. (See note EXP. 25).

EXP. 5.—Connect **H** and **O** holders with oxy-hydrogen blowpipe, and igniting the **H** first, turn on the **O**. Place small piece of fine **Pt** wire (fused into glass holder) in the flame. It melts. [The rubber cork in the **H** holder should be well oiled and firmly bound down by strong twine fastened to shoulder of the bottle. The **H** should be drawn into a test tube over water and tested *before* it is burned in the blowpipe. If it burns quietly after taking fire it is safe to ignite jet. If it burns explosively, it is mixed with air and must not be ignited. The holder is first filled *completely* with water and the **H** or **O** (from generator as frontispiece 2) pressed backward expelling the water, the reservoir being kept so that the water in it shall be only about a decimeter above the water in the holder].

EXP. 6.—Into a tube closed at one end (through which **Pt** wires are fused) filled and inverted over mercury, put 2 cu. cm. of **O** and 4 cu. cm. of **H** and explode by electric current. The mercury rises and with the water above completely fills the tube (except perhaps a bubble of gas, which is the result of inaccurate measurement). Composition of water is proved by *synthesis*, as nothing is found dissolved in the water.

Quantitative Test for Carbonic Oxide in Schoolrooms (as an index of the amount of poisonous "animal vapor" present.)

The proportion of carbonic oxide is generally estimated *by volume* and on a scale of so many parts in 10,000 of air. In pure out-door air there are about 4 parts of carbonic oxide in 10,000 of air. In the schoolroom the proportion should never rise above 8 parts. Examination of the following reactions and explanations will reveal the simplicity of the test.

$$\underset{\substack{\text{barium}\\\text{hydrate.}\\171}}{Ba\ 2\ H\ O} + \underset{\substack{\text{crystalized}\\\text{oxalic acid.}\\126}}{H_2\ C_2\ O_4.\ 2\ H_2\ O} = \underset{\substack{\text{barium}\\\text{oxalate.}}}{Ba\ C_2\ O_4} + \underset{\text{water.}}{4\ H_2\ O}.$$

$$\underset{171}{Ba\ 2\ H\ O} + \underset{44}{C\ O_2} = Ba\ C\ O_3, + H_2\ O$$

In neutralizing power.

126 gms of cr. oxalic acid = 171 gms of barium hydrate.
44 gms of $C\ O_2$ = 171 " " "
therefore 44 gms of $C\ O_2$ = 126 " of cr. oxalic acid.
1 grm $C\ O_2$ = 2.863 + gms, or 2863 mgs of cr. ox. acid.

If we weigh carefully 2863 mgs of cr. oxalic acid (*not deliquesced*) and dissolve in 1000 cu. cm. (litre) of water, then 1 cu. cm. of that "standard" solution will equal (in neutralizing power) *1 millegram* of carbonic oxide. [Keep solution in dark bottle.]

We then make a solution of barium hydrate dissolving about 5 gms in a litre of water.

Suppose a jug (bottle) with tight fitting rubber cork holds 4155 cu. cm (carefully measured), which jug we fill from the air of the schoolroom by means of a small bellows (blown a sufficient number of times, say 25), and take temperature of the room at the same time as 20°. Into this we pour from a sp. gr. bottle (holding with the glass stopple in, 100 cu. cm.) 100 cu. cm. of the barium hydrate solution and shake thoroughly at intervals. We now fill the burette (frontispiece 5) with the "standard" solution of oxalic acid, to a point a little above 0 and run it down carefully drop by drop to the 0 point precisely. Measuring from barium hydrate solution (by means of another sp. gr. bottle holding 50 cu. cm.) 50 cu. cm. we pour it into a clean, wide-mouthed bottle and add a little blue litmus solution. We now open the burette and allow the acid to run slowly (the last drop by drop) into the wide-mouthed bottle containing the 50 cu. cm. of barium hydrate solution. It takes say 24.5 cu. cm. of acid to neutralize the alkali—(when the last drop needed is added the litmus suddenly turns red). Now carefully fill the second sp. gr. bottle (previously carefully rinsed in distilled water) with the solution taken from the jug containing the schoolroom air (but this solution should previously have been poured into a bottle just big enough to hold it, excluded from the air by stopple and poured off carefully after it has *completely* settled. This excludes the barium carbonate, a very necessary thing in the test.) Again fill the burette as before and see how many cu. cm. of the acid are required to neutralize the 50 cu. cm. taken from the jug. We find in every case it requires *less*, because the carbonic oxide in the jug has already neutralized part of it. It requires, say, 22 cu. cm. of the acid. 24.5 cu. cm.—22 cu. cm.=2.5 cu. cm. But from equations above we know that 1 cu. cm. of the acid corresponds to 1 mg. of carbonic oxide; therefore as we poured out only one-half of the alkali to test there were 5 mgs. of carbonic oxide in the jug. From table we see that 1 mg. of carbonic oxide at 20° occupies .544470 cu. cm. of space, therefore 5 mgs. occupy 2.72235 cu. cm. The question then becomes,—If in 4055 (4155–100) cu. cm. air there are 2.72235 cu. cm. of carbonic oxide, how much carbonic oxide in 10000 cu. cm. of air? We have the proportion **4055: 10000:: 2.72235: ——**
from which we obtain 6.7 parts in 10000 as the answer, that is the room is fairly ventilated.

Space occupied by 1 mg. of $C\ O_2$ *at different temperatures (barom. 760 mm.)*

Degree. C	Degree F	Cubic Cm.	Degree. C	Degree. F	Cubic Cm.	Degree. C	Degree. F	Cubic Cm.
0	32	.507306	21	69.8	.546328	28	82.4	.559336
15	59	.535178	22	71.6	.548186	29	84.2	.561194
16	60.8	.537037	23	73.4	.550044	30	86.	.563052
17	62.6	.538895	24	75.2	.551903	31	87.8	.564910
18	64.4	.540753	25	77.	.553761	32	89.6	.566769
19	66.2	.542611	26	78.8	.555619	33	91.4	.568627
20	68	.544470	27	80.6	.557477	34	93.2	.570485
						35	95.	.572343

A factor can be worked out for each jug used and for each temperature, so that by a simple multiplication of the difference shown by the burette the result is obtained. Any bright pupil can master the test in a few hours and can apply it in a few minutes by using factors. The test can be made after school or before school the next day. Such tests regularly reported would do much to awaken an interest in having a proper system of ventilation. Abominable is too tame a word to use for the ventilation *"enjoyed"* by many schoolrooms.

METRIC SYSTEM.

LINEAR		CAPACITY.	
10 Millimetres (mm.)	= 1 Centimetre (cm.)	10 Millilitres	= 1 Centilitre
10 Centimetres	= 1 Decimetre (dcm)	10 Centilitres	= 1 Decilitre
10 Decimetres	= 1 METRE	10 Decilitres	= 1 LITRE
10 Metres	= 1 Dekametre	10 LITRES	= 1 Dekalitre
10 Dekametres	= 1 Hektometre	10 Dekalitres	= 1 Hektolitre
10 Hektometres	= 1 Kilometre	10 Hektolitres	= 1 Kilolitre

WEIGHTS.	
10 Milligrams (mg.)	= 1 Centigram
10 Centigrams	= 1 Decigram (dcg.)
10 Decigrams	= 1 GRAM (gm.)
10 Grams	= 1 Dekagram
10 Dekagrams	= 1 Hektogram
10 Hektograms	= 1 Kilogram (kgm.)

1 Metre (meter)	= 39.37 inches.
1 Litre	= 61 cubic inches
1 Litre	= 1 cu. decimetre
1 Gram	= 15.43 grains
1 Gram	= weight of 1 cu. cm. of water (4°)
1 Kilogram	= 2 1-5 lbs.
1 Kilogram	= weight of 1 cu. dcm. (litre) of water (4°)

REFERENCE TABLE No. 2—CONTINUED.

NEGATIVE GROUPINGS.

Monad.

- $\overline{PO_3}$ = metaphosphate
- $C_5H_9O_5$ = valerianate
- $\overline{CNO}$ = cyanate
- $\overline{CHO_2}$ = formate
- $C_4H_7O_2$ = butyrate (butter)
- $C_7H_5O_2$ = benzoate
- NO_2 = nitrite

Dyad.

- $\overline{C_3H_4O_3}$ = lactate
- $\overline{C_5H_2N_4O_3}$ = urate
- B_4O_7 = tetraborate (borax)
- MnO_4 = manganate
- Mn_2O_8 = permanganate
- Cr_2O_7 = bichromate

Triad.

- $C_4H_3O_5$ = malate
- C_7HO_7 = meconate (opium)
- $C_7H_3O_5$ = gallate
- $C_{27}H_{19}O_{17}$ = tannate

Tetrad

- $Fe(CN)_6$ = ferrocyanide

Hexad

- $Fe_2(CN)_{12}$ = ferridcyanide

Monad

POSITIVE GROUPING.

- H_2N = amidogen

I. ADD **H Cl**..... FILTER.

Precipitate.....insoluble chlorides Hg_2Cl_2(ous) Ag Cl and $Pb Cl_2$. Wash, boil thoroughly and filter.

Filtrate..soluble chlorides of other metals, as—As, Sb, Sn, Cu, Fe, etc. and also of Hg (ic).

Precipitate....Hg_2Cl_2 and Ag Cl. Wash with hot water and add warm H_4NHO (Ag Cl dissolves)

Precipitate H_2NHg_2Cl, amido mercurous chloride, *black*.

Add two or three drops aqua regia. Dilute with ten drops of water, and evaporate filtrate *nearly* to dryness at *low heat* (Water-bath is best.) Again dilute with 20 drops of water, and filter. Test as in Ex. 121.

Filtrate..Ag Cl. Add HNO_3 to acid reaction. Ag Cl is reprecipitated because its solvent is neutralized. Wash, and fuse on charcoal with a little K_2CO_3

$K_2CO_3 + 2 Ag Cl = Ag_2CO_3 + 2 K Cl$

$Ag_2CO_3 = Ag_2O + CO_2$

$2 Ag_2O + C = CO_2 + Ag_4$, silver globules.

No incrustation on charcoal as in lead reaction.

Filtrate..$Pb Cl_2$ Divide into three portions and to the

1st add H_2SO_4

$Pb Cl_2 + H_2SO_4 = PbSO_4 + 2 HCl$

white precipitate

2d add $K_2Cr_2O_7$

$2 Pb Cl_2 + K_2Cr_2O_7 + H_2O =$ (bichromate)

$2 Pb CrO_4 + 2 K Cl + 2 H Cl$

chrome yellow precipitate

3d add $(H_4N)_2S$

$Pb Cl_2 + (H_4N)_2S = PbS + 2 (H_4N Cl)$

brownish black precipitate

Fuse with *little* K_2CO_3 on charcoal.

$K_2CO_3 + PbS = PbCO_3 + K_2S$

$PbCO_3 = PbO + CO_2$

$2 PbO + C = CO_2 + Pb_2$

(lead globule, *malleable*). Bi and Sb are brittle. Heat globule in oxidizing flame of blow-pipe; a *yellow* incrustation (Pb O) appears upon the charcoal.

II. Pass H_2S gas through Filtrate from First Group

Precipitate Cu Hg_2(ic) Pb Bi As Sb Sn (Au Pt). Collect, wash, digest in $(H_4N)_2S$.

Filtrate Soluble sulphides of other metals.

Precipitate Cu Hg_2(ic) Pb Bi. Wash, boil in HNO_3, filter

Filtrate As Sb Sn (AuPt) Add dilute H Cl, filter, drain well, add *strong* H Cl boil, dilute slightly, filter.

Ppt. Hg_2 (ic). Black. Confirm by Exp. 121 in original filtrate.

Filtrate Cu Pb Bi Add H_4NHO, filter.

Precipitate Pb Bi Wash, add a few drops HNO_3 dilute, filter.

Ppt. Bi. Fuse on charcoal with K_2CO_3 Brittle globule.

Filt. Pb Dilute, add H_2SO_4 set aside White ppt.

Filtrate Cu. Test as in Exp. 125, after adding a drop of sulphurous acid.

Ppt. As. Yellow. Confirm by Exp. 111

Filtrate..Sn Sb. Pour into H-apparatus, and obtain an immonial spot, Exp. 113.

Sn remains on Zn. Dissolve in hot HCl dilute, add H_2S; a brown ppt. of Sn S falls.

Sb (spot). Test as in Exp. 113.

Au and Pt rarely occur in solution. Au may be tested for as in Exp. 115. Ammonium chloride gives a yellow, crystalline precipitate with solution of $PtCl_4$.

III.

To Filtrate from Second Group add H_4 N H O and $(H_4 N)_2 S$. Warm gently and filter.

Precipitate..Co Ni Fe Mn Cr Zn Al Warm gently in *dilute* (5 per cent.) H Cl.	Filtrate. Soluble compounds of other metals.

Precipitate..Co Ni		Filtrate Fe Mn Cr Zn Al. Evaporate nearly to dryness; add Na HO, and boil, filter.	
Fuse a portion in borax bead. Blue color indicates Co.	Add three drops aqua regia to remaining portion, and evaporate to dryness. Warm with few drops of Co Cl_2, and dry on white paper. Green color shows Ni.	Precipitate Fe Mn Cr Fuse with minute quantity of potassium carbonate and nitrate.	Filtrate..Zn Al Add H_2 S in excess, filter.
			Ppt. Zn Slaty white.
			Filtrate Al Add H Cl to acid reaction, boil, filter, and to filtrate add ammonium hydrate to alkaline reaction. A flocculent precipitate indicates Al (Aluminium hydrate).
Deep green indicates Mn (potassium manganate). Boil, filter.			
Precipitate..Fe Add tannic acid, and boil; brownish-black solution = Fe.	Filtrate..Cr Add acetic acid, boil violently; add lead acetate. Chrome-yellow ppt. indicates Cr.		

IV.

To Filtrate from Third Group and H_4 N H O, H_4 N Cl and $(H_4 N)_2 CO_3$.

Precipitate..Ba Sr Ca. Boil in *little* dilute H Cl, and filter. Ba (alone) gives green by EXP. 131. Sr, by same method, *red;* and if neither color is seen, Ca alone gave the precipitate of this group. (If all three are present, they are separated with some difficulty.)	Filtrate Soluble compounds of metals of the fifth group.

V

To Filtrate from Fourth Group add H_4 N H O to alkaline reaction and then H Na_2 PO_4. Filter.

A crystalline precipitate of N H_4 Mg PO_4 indicates Mg.	In filtrate, test for Na and K by *flame* color.

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CHEMICALS.

Acetic Acid	8 grms.	Magnesium sulphate	5 grms.
Alcohol	1 litre.	" ribbon	1 dcm.
Alum	8 grms.	Manganese dioxide	100 grms.
Ammonia water	100 "	Mercuric chloride	1 "
Ammonium chloride	4 "	*Mercuric cyanide	
" carbonate	10 "	Mercury	5 kgm.
Aniline blue	1 "	Nickel	1 grm.
Antimony	4 "	Nitric Acid	100 "
Tartar Emetic	1 "	Tannic acid	1 "
Arsenous oxide (white arsenic)	2 "	*Olive oil	8 "
Barium chloride	2 "	Oxalic acid	2 "
" nitrate	4 "	*Picric acid	1 "
" hydrate	4 "	Phosphorus	1-20 stick
Bismuth	2 "	*Potassium (under naptha)	.5 grms.
Borax	4 "	Potassium bichromate	5 "
*Carbon bisulphide	2 "	Potassium carbonate	10 "
Citric Acid	2 "	Potassium chlorate	80 "
Cobalt Chloride	1 "	*Potassium ferrocyanide	5 "
Copper Sulphate	7 "	Potassium hydrate	5 "
Ether (common)	5 "	Potassium iodide	2 "
Fluor Spar	7 "	Potassium permanganate	1 "
Gold Leaf	¼ sheet	Silver nitrate	5 "
Gum shellac	5 grms.	Sodium (under naptha)	.5 "
Hydrochloric acid	100 "	Strontium (nitrate)	2 "
Indigo	1 "	Sulphur (brimstone)	10 "
Iodine	1 "	Sulphuric acid	200 "
Copperas (iron sulphate)	4 "	Tin	2 "
Ferrous sulphide	7 "	Tin chloride	5 "
Lead acetate	10 "	*Tartaric acid	2 "
Lead oxide (litharge)	5 "	*Turpentine	3 "
Litmus paper (red and blue)	1 sq. dcm.	Zinc (drop)	25 "

APPARATUS.

2 Flasks. (*1 Flask).
1 Alcohol Lamp.
1 Evaporating Dish.
*2 Beakers.
6 Test Tubes (*3)
*1 Mortar and Pestle.
1 Blow Pipe.
1 metre Glass Tubing.
3 dcm. Rubber Tubing.
1 Iron Wire Gauze, (¼ sq. dcm.)
1 Three-cornered File.
1 Round File.
1 Platinum Wire, (1 dcm).
3 Rubber Corks.
*1 Pair Scales (metric weights).
1 Measuring Glass (metric).
3 dcm. Copper Wire.
3 sheets Filtering Paper.

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NOTE.—Marble, Lime, Charcoal, Old Watch-springs, Common Salt, Sh hydrofluoric acid experiment), Sugar, Raisins, Beeswax, Iron Wire (fo stand), Plates, Soda Bottles (for receivers), Pan (for pneumatic tub), can be obtained with little difficulty.

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